PROBLEMS, PROJECTS, AND EXPERIMENTS IN BIOLOGY

ATWOOD

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BY THE SAME AUTHOR

CIVIC AND ECONOMIC BIOLOGY

"This latest addition to civic biology offers a new viewpoint in science teaching, and in giving prominence to the practical phases of the science"—General Science Quarterly (Mass.)

COMPARATIVE VERTEBRATE DISSECTION

This volume is the result of many requests from teachers for a manual "different" from those now in use. The book prepares the student for a continuation of the study to its logical conclusion in university courses.

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PROBLEMS, PROJECTS, AND EXPERIMENTS IN BIOLOGY

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BY
WM. H. ATWOOD, M. A., M. S.
MILWAUKEE STATE NORMAL SCHOOL

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FOREWORD TO TEACHERS AND STUDENTS

The contents of this manual are arranged to correspond in sequence with the author's *Civic and Economic Biology*, but it has been assembled with the thought in mind that it may be used with other texts. If copies of *Civic and Economic Biology* are available as references, this manual should be adapted to any course in biology, either with or without a special text. With this in mind, references to various biological works have been placed below the sectional headings. It is the author's hope that the references cited will be available to the students in the laboratory.

Laboratory work is naturally so dependent upon conditions which obtain, both within the laboratory and in the environment of the school, that it is best to have a considerable variety of exercises suggested from which selections may be made. It is hardly to be expected that all of the exercises suggested here will be worked out, or that they will be taken up, in all cases, in the order given. They are all workable, and something of value may be learned from each. Experiments which often fail, or give indifferent results, have been eliminated. Those which have been selected should stimulate thought. A problem requires thought for its solution.

Class spirit and cooperation are stimulated if student committees are appointed or elected to assist the instructor. Students should feel that they are as reponsible for the success of the course as the teacher. The membership of the committees should be changed from time to time so that each student will serve in a variety of activities. If the class is well organized, a diversity of work may go on at one time; but under unfavorable conditions it will be more necessary to keep all members working at the same problem at a given time.

Variation in the content and method has been especially sought. Students soon lose interest in a drawing course, or a laboratory course in essay writing. Teachers also enjoy a course more if it can be made to vary in method and content from year to year.

There should be a difference between a problem, a project, and an experiment; but the difference is more in the point of view of the student and teacher than in the exercise itself. Do not make experiments of mere demonstrations. It is not necessary that all things be taught by the problem method. Simple things should be simply taught.

The directions are stated very briefly. The student should be given an opportunity to make mistakes. They should have an educational value. Directions which are given in too great detail eliminate opportunity for initiative. Students should ask few questions of the teacher and should solve their own problems.

Quizzes should be frequent and should cover all reports, topics, demonstrations, field trips, etc. A quiz is a review. Everything should be reviewed. Students are responsible in the quiz for the projects of others which have been presented to the class. Experience has shown that students study better if quizzes are frequent and searching. Written work should be handed in daily, as it is ready, and that which fails to equal the standard of the course should be rewritten. Teachers and committees should return students' papers promptly.

Advance preparation should be made for many laboratory problems and projects. Look ahead in the manual and make arrangements for such exercises. Seedlings require from two to three weeks to sprout and start their growth. Paramecia cultures should be started about two weeks before they are to be used. Some materials which can be collected in the fall for winter use should be carefully preserved. Reports and topics should be assigned in advance and should be ready when the study with which they are connected is before the class.

The illustrations have been selected with great care as to their teaching value and also for their scientific accuracy and artistic qualities. Good illustrations are a stimulus to the student. Those which have been borrowed are credited in the legends.

It is the hope of the author that the use of this manual will ensure both enjoyment and efficiency to the courses in the biological sciences where it is used.

Wm. H. Atwood.

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PROBLEMS, PROJECTS AND EXPERIMENTS IN BIOLOGY

1. ORGANIZATION

References

Civic and Economic Biology, Atwood, Preface and Study 1.
Civic Biology, Hodge and Dawson, Chaps. I and II.
Elementary Biology, Gruenberg, Preface and Chap. I.
Biology for Beginners, Moon, Chap. I.
Hunter's Biologies, Preface and Chap. I.
The Teaching of Biology, Lloyd and Bigelow.
Principles of Science Teaching, Twiss, Macmillan Co.
The Teaching Botanist, Ganong, Macmillan Co.

1. Soon after the beginning of the school year, it will be well to hold an election and choose committees to attend to the business of the class. The **library committee** should have charge of the books and the bookcase. A good system of cataloguing should be instituted, and every book should always be in its place at the close of the day. The **archives committee** should have charge of all papers and reports which are produced by the members of the class. The **museum committee** should have charge of the museum cases and should see that all specimens are kept in good order. The **committee in charge of apparatus** should see that the equipment which belongs to the department of biology is conserved and put away in good order. The **supplies committee** should purchase for the instructor such materials as are to be bought locally and should keep the materials used in the course in good order. The **committee on ventilation and sanitation** should assist the instructor in such matters as lighting, fresh air, heating, cleanliness, etc. There should be one or more committees in charge of the **plants** and **animals** which are kept alive in the department. Are there any other committees which should be appointed? Remember that loyalty to duty and a wholesome spirit of cooperation are the prime essentials which

make for a successful course in biology. The class expects every one to do his duty promptly.

2. INORGANIC MATTER

References

Civic and Economic Biology, Atwood, Study 1.
Introductory chapters of other biologies.

2. Exhibit of Kinds of Matter.—The **supplies committee** should arrange an exhibit of chemical elements, chemical compounds, and minerals. Place them in three groups and label each specimen. Make such remarks to the class as may seem appropriate, and have the names of the specimens learned by the students.

Prepare another similar exhibit of carbohydrates, fats, and proteins.

Understand that the chemical composition of living things and their products is much more complex than that of minerals.

3. Crystallization.—Heat about a half cupful of water to boiling and add as much copper sulphate as will dissolve in the boiling water. Pour the liquid into a dish and let it cool. Watch the formation of crystals of copper sulphate.

Dissolve some more copper sulphate in warm water and put it away to evaporate slowly. The crystals which form in this way should be larger. Why? Try to get crystals of the following by this method: ammonium nitrate, sugar, salt, glucose, starch, glue, potassium sulphate, potassium chlorate, and potassium dichromate. Each student should not try all of the above mentioned materials, but if each takes one, results may be compared. Do they all form crystals? Are the crystals of each salt alike?

4. Draw diagrams of some of the crystals.

5. Irritability.—Pour a small amount of a solution of silver nitrate into each of four test tubes. To the first add some sodium chloride solution. To the second add some sodium bromide solution. To the third add some sodium iodide solution, and leave the fourth as it is. Place them in the sunlight. How long does it take to change the color?

6. Report.—Some student may prepare a topic on the subject, The Chemical Changes Produced by Light on Silver Salts. See a chemistry, or a book on photography.

3. CHARACTERISTICS OF LIVING MATTER

See the same references as in the preceding section.

7. Growth.—Committees or individuals may study some of the following phenomena of growth and report to the class.

How rapidly do leaves come out of the bud? In what ways are various leaves and flowers folded in buds? Do stems grow in length after they are once formed? How do they increase their diameters, by adding to the outside or throughout the entire stem? Do leaves reach a certain size and then stop growing? Is the color of young leaves lighter or darker than old ones? Which plants grow the more rapidly, vines or plants with heavy stems?

8. Plant some seeds and note the growth of the roots. Do they increase in diameter? Do they grow only at the tips, or throughout their entire length? In a young seedling, are the roots or the leaves the more extensive?

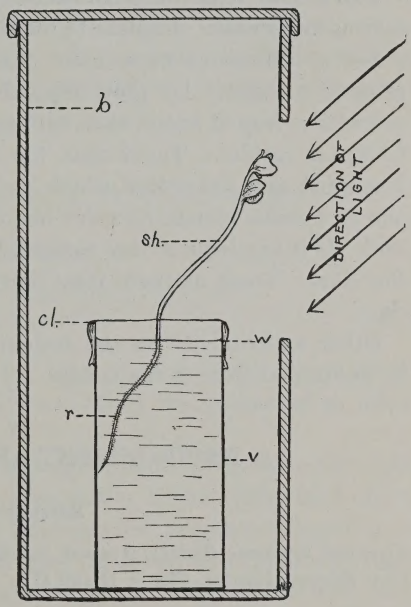


FIG. 1.—Diagram of a chamber to show phototropism. (*Fundamentals of Botany, Gager.*)

9. How long does it take the following animals to become fully grown: fly, potato beetle, snake, turtle, cow, sheep, dog, chicken, robin, man, elephant? How long does it take the eggs of the following birds to hatch: robin, chicken, duck?

Compare the proportions of the parts of a young dog with those of an old one. How do they change as the puppy becomes a dog?

10. Irritability.—If a specimen of *Mimosa* is growing in the laboratory, touch its leaves and note how they respond. If no plant is

available, plant some seeds and have one ready for observation later.

Place a young, rapidly growing weed, or some other plant, in a dark box with light admitted through only one side. After a few days note its response to light. Observe the leaves of the plants in the windows and other places. How are their leaves arranged in reference to the light?

Can a committee find a compass plant and bring it into the laboratory as an exhibit. Explain to the class just how it grew.

Let a committee experiment with earthworms to find if they respond to light. Do they respond to a jar? To sound? Touch one with a drop of water, then with salt water, then with a weak acid. Compare results. Touch first the head and then the tail with a toothpick and determine which end is the more sensitive. Place one on a moist blotter on a dry board. Will it crawl off of the blotter? Is it sensitive to dry surfaces? Report all of these results to the class. Some of them may be repeated in the presence of the class.

Other experiments on the responses of plants and animals will be performed later in the course.

4. ENVIRONMENT AND ADAPTATION

References

Civic and Economic Biology, Atwood, Studies 2, 3, and 4.
Civic Biology, Hunter, Chaps. II and III.

11. Field Trip.—The class should be divided into troops of three to six students each for the study of the various features of the environment in the vicinity of the school. One group may study a meadow, another a brook, another a pond, and another a woods. Make out a plan of what you expect to study before you start. Never go on a field trip without a notebook. Keep a record of what you find. Note the conditions of light, heat, moisture, abundance of plants and animals, soil, and the kinds of life found in each region. Bring samples and specimens to the laboratory for exhibition and discussion on the day following the excursion. Write lists on the

board of the kinds of plants and animals found in each locality and compare.

Do not wear your best clothing on field trips. Expect to get your feet muddy. Those who visit a pond or brook should have a net to secure the small animals which live there. Water-tight vessels should be provided to bring home the catch. Bags and baskets will be convenient.

12. Project.—Let each student of the class choose a plant or animal and make a special study of its relation to temperature, water, light, air, soil, food, and shelter. The results should be written up and filed with the **archives committee.** Some of the most interesting ones should be read to the class.

5. THE GOLDENROD, A TYPICAL PLANT

References

Civic and Economic Biology, Atwood, Study 5 and Fig. 176.
Wild Flowers, Blanchan, Doubleday, Page & Co.

13. Field Trip.—Read *Study* 5 in Atwood's Biology, and make arrangements to go on a field trip **to study the goldenrod or some other typical plant.**

Where do they grow? What kind of soil? What are the light and moisture conditions of their habitat? What other plants grow with them? Are they more or less vigorous than their competitors? Are they more or less numerous than all of the other kinds of plants in their vicinity? How do they compare in this respect with any one kind? How do they rank in abundance as compared with each of the other kinds of plants growing with them?

How tall is the highest plant which you can find? What gave it this advantage? Does it bear more seeds than the others? What is the average height of goldenrods? Compare them with other plants in their environment in this respect.

Note the color of the **flowers.** Estimate the number of individual blossoms in a large and an average sized flower cluster. If some have gone to seed, count the number of seeds to a flower and to a cluster. Scatter some seeds in the wind and watch them sail. Do they sail

as well as the dandelion seeds? What is the advantage in having the blossoms in a cluster?

Note how tall the **stems** are. Are they branched? Why would it be poor economy to have them branched at the bottom?

How are the **leaves** arranged on the stem? Where are the ones which are dying? Why do they die first? Note the shape of the leaves. Does each get relatively more light than it would if they were broad and large? Does this same principle hold for blades of grass?

Find a plant which is growing in loose soil and dig it up. Find its underground stems and its roots. What is the color of each? Are there any scales on the stems? What are the scales morphologically? Do you think much food could be stored underground? How many plants would have grown from the one which you dug out the next spring? What is the use of the underground stem?

Capture as many of the various **insects** inhabiting the goldenrod as you can. There will be beetles, bees, flies, and butterflies. Assign them to one of these groups. Have a separate receptacle for each group and take them to the laboratory where students may find what their names are as a project. What were the insects doing on the goldenrod? Are any of them of any benefit to the plant?

Bring some goldenrod and other plants to the class-room for reference during the quiz which follows the field trip.

6. INSECT STUDY

References

College Zoology, Hegner, Macmillan & Co.
General Zoology, Pearse, Henry Holt & Co.
Civic and Economic Biology, Atwood, Studies 6, 64, 65, and 66.

14. Laboratory Work.—The **grasshopper** is the largest of the common insects, and it is of a generalized type of structure. These facts, together with its abundance, make it a favorite for laboratory study as a typical insect. If the natural history of the insect is to be studied, the **bee** is considered superior. See Atwood's Biology, *Study* 6, also pp. 411 and 412. Large lubber grasshoppers may be had from the dealers, or smaller ones may be caught locally.

Make a sketch of the side view of the grasshopper to show the features mentioned below. The body of an insect is divided into three divisions,—the **head, thorax,** and **abdomen.** Find the large **compound eyes.** Examine them with a lens to see the facets. Can the grasshopper see in all directions at one time without moving his head? The three **simple eyes** will be seen with the aid of a lens. One is in the middle of the face, and another before each compound eye. They appear as small beads.

The **antennæ** are possessed of how many joints? How great is their range of movement?

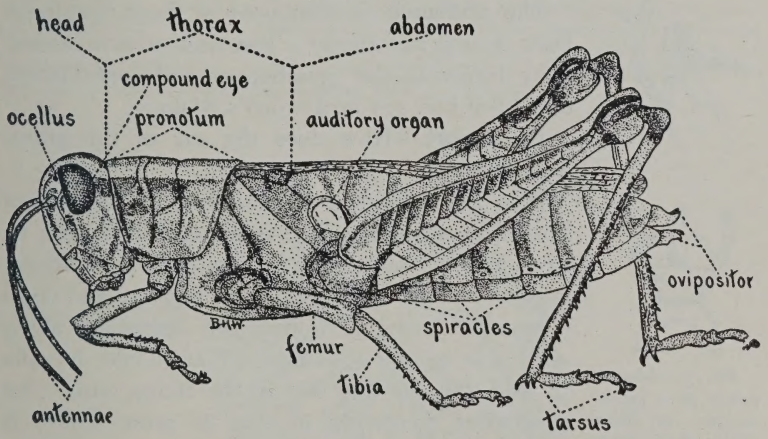


FIG. 2.—External view of a grasshopper to show its parts. (*After Walden, Connecticut Geological and Natural History Survey, Bulletin No.* 16.)

The **mouth parts** are shown here and in Figs. 328 and 329 in Atwood's Biology. Find them in your specimen and learn the names of their parts. They may be arranged as in Fig. 329 and drawn.

The **thorax** is composed of three parts (somites). The first is called the **collar.** It is movable on the body. Note that it bears the first pair of legs. The second division bears a pair of wings and a pair of legs as does the third. The divisions of the thorax are called the **prothorax, mesothorax,** and **metathorax.**

Compare the two pairs of **wings.** Which pair does the most of the flying? How does the grasshopper make its sounds? Do you know how the katydid, cricket, and cicada make their sounds?

Study the **leg** of an insect. The first two parts are small and difficult to make out. They are the **coxa** and **trochanter.** The **femur** is the largest part of the leg. It is followed by the slender **tibia,** and the foot is the **tarsus.** Compare the legs of the grasshopper with those of other insects.

FIG. 3.—Mouth parts of a grasshopper. *m*, Mandible; *max*, maxilla; *L*, labium; *p*, palps. (*Elements of Animal Biology, Holmes.*)

Draw an insects' leg and label the parts.

The **abdomen** is composed of rings (somites). How many are there? The first ring is incomplete below in the grasshopper and contains the ear. See Fig. 121 in Atwood's Biology.

15. Report.—How does the ear of the grasshopper work?

If a live specimen is available, its respiration should be observed. The abdomen will be seen to swell and contract as air is taken into the **tracheal system** and let out again. See Figs. 33 and 96 in Atwood's Biology. Count the **spiracles** along each side of the abdomen. You should be able to find two on each side of the thorax also. An **ovopositor** consisting of two or more spines is usually found at the end of the abdomen of female insects.

16. Report.—How do grasshoppers lay their eggs?

17. If it is desired to study the **internal anatomy** of an insect, a committee may be asked to find suitable directions in a manual and copy them on the board.

18. Exhibit.—The **museum committee** may prepare an exhibit to show one or more insects of each of the common orders of the class Insecta. Notes which state the differences which distinguish the orders may be made to accompany the exhibit. The notations will be somewhat like the following table:

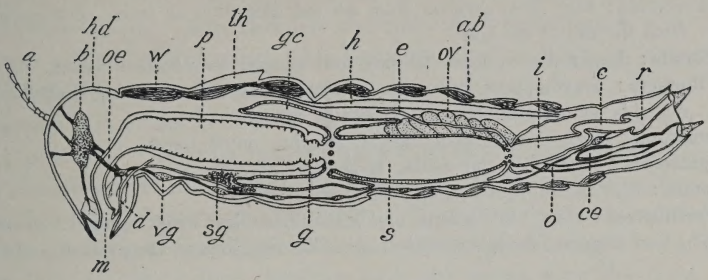


FIG. 4.—The internal anatomy of the grasshopper. The regions of the body are: *hd*, Head; *th*, thorax; and *ab*, abdomen. The regions of the digestive tract are: *m*, Mouth; *oe*, esophagus; *p*, pouch; *g*, gizzard; *gc*, gastric cæca; *s*, stomach; *i*, ileum; *c*, colon; and *r*, rectum. Other parts are: *a*, Antenna; *b*, brain; *ce*, cement gland; *d*, duct of salivary glands; *e*, excretory tubules; *h*, heart; *o*, oviduct; *ov*, ovaries; *sg*, salivary glands; *vg*, ventral ganglia of nervous system; *w*, wall of body. (*Elementary Zoology, Galloway.*)

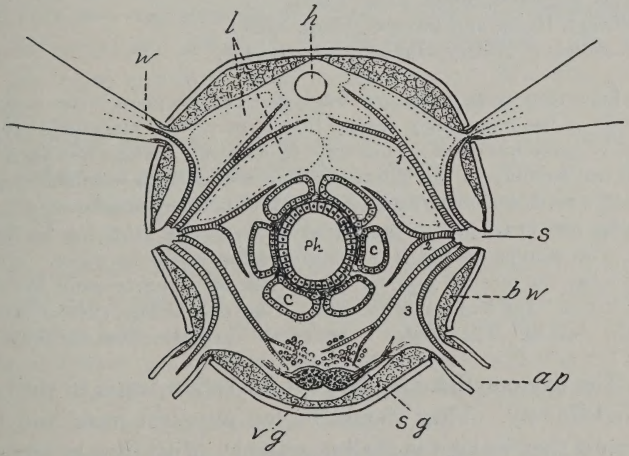


FIG. 5.—Cross section of the body of the grasshopper through the thorax. *ap*, First joint of leg; *bw*, body-wall which is made up of cuticula, skin, and muscles; *c*, gastric cæca; *h*, heart; *l*, spaces of body-cavity; *ph*, pouch; *s*, spiracle; 1–3, tracheal tubes; *sg*, salivary glands; *vg*, ventral ganglion; *w*, wing. (*Elementary Zoology, Galloway.*)

Aptera: silver-fish; no wings, body covered with scales.
Ephemerida: May-flies; delicate four winged flies, two or three setæ project from the end of the body.
Odonata: dragon-flies and damsel-flies; four winged, long bodied insects.
Orthoptera: grasshoppers, crickets, roaches, katydids, walking-sticks, and mantids; chewing mouth parts, straight wings.
Hemiptera: bugs, cicadas, scale insects; piercing mouth parts.
Lepidoptera: butterflies and moths; large scaly wings.
Diptera: flies and mosquitoes; only one pair of wings.
Hymenoptera: ants, bees, wasps, and ichneumon-flies; wings hooked together.

The best reference for this work is *General Zoology*, Pearse, Henry Holt and Co.

7. THE CRAYFISH (CRAWFISH)

References

Civic and Economic Biology, Atwood, pp. 30, 138, and 142.
General Zoology, Linville and Kelly, Ginn & Co.
Practical Zoology, Hegner, Macmillan Co.
Biology for Beginners, Moon, Chap. XXII.
Civic Biology, Hodge and Dawson, Chap. XXVI.
New Essentials of Biology, Hunter, Chap. XVIII.

The laboratory work on the crayfish is given at this place in the manual, but the needs of the course may require that it be studied elsewhere. No large amount of space was given to this form in Atwood's Biology because it can be studied satisfactorily in the laboratory, and it is of little economic and civic value. However, it has long been a favorite for laboratory dissection.

Crayfish may be taken from the ponds and brooks where they live by fastening a piece of fat meat on the end of a string and casting it into the water. When the animal seizes the meat, it may be drawn from the water before it has time to "think it over" and let loose of the bait. They may be had, alive or preserved, from the dealers. The lobster is better for dissection, because it is larger.

19. **The live crayfish** may be kept in shallow water in the laboratory indefinitely. They should be fed pieces of meat and bread. Why must they be kept in shallow water? Must they be allowed an opportunity to come to the surface? Why do they come to the surface? How do they seize their food? How is it held while it is being eaten? How does the crayfish walk? Which legs push and which pull? Are the pinchers used in walking? How many **legs** are there? Do they all have claws on their ends? Compare the legs

with those of the grasshopper. Note how the feelers are used. How many are there? The smaller ones are called **antennules,** and the larger are called **antennæ.** Find the **eyes.** Can they be moved? Find the large fin-like structure at the end of the tail. Throw a crayfish in a vessel of deep water and learn how it swims. Describe the process. Does the crayfish prefer to hide under something or to remain out in the open? Take one out of the water and place it on the desk. How does it retreat? How does it make a defense when retreat is not possible? With a piece of glass tubing force some red ink or other colored solution into the water near the head of the crayfish. Note by this how the water circulates through the **gill chambers** on the sides of the body. Watch the **swimmerets** in their rhythmical movements under the abdomen (tail).

The dead crayfish will be colored red if it is preserved in formalin. What are the natural colors of crayfish? Are they all of the same color? Are their colors protective?

Note the two body divisions in the dead specimen. The head and thorax are combined in one piece, called the **cephalothorax.** The part commonly called the tail is the **abdomen.** The **mouth parts** are more numerous than in the insects. The first pair are hard and are called the **mandibles.** The second and third pair are called the first and second **maxillæ** respectively. The three pairs which follow are called **maxillipeds.** There are, then, six pairs of appendages which have to do with eating, but the posterior pairs are not of so much importance as the anterior ones. The posterior pairs also help in passing water over the gills. Remove the mouth parts and place them in a series on a sheet of paper. When they are arranged have them inspected. If they are all perfect, they should be drawn and labeled. Not all students will succeed in getting all of the parts out entire. They should be removed with the greatest care with sharp pointed tweezers.

Draw a cheliped, a leg, a swimmeret, and the telson.

The crayfish is a somited animal. Count the rings in the abdomen. The telson may or may not be counted, as you like. Are there evidences of segmentation in the cephalothorax?

Dissect the animal by opening the shell (**carapace**) on the back and cutting it away. The **stomach** is a large sac in the head end of

the body. Cut it open and find the "**teeth**" which it contains. What are they used for? Just back of the stomach is the **heart.** It is a mere sac with muscular walls. On the sides of the stomach and heart are the **reproductive organs.** Nearer the legs and also on the sides of the stomach are the halves of the **pancreas.** This is a large glandular organ which secretes digestive juices. The **green glands** are situated below the stomach on either side of the head. (The glands are not always green.) They are excretory and discharge their fluid through openings in the bases of the antennæ. Trace the **intestine** through the abdomen and note the strong muscles through which it runs.

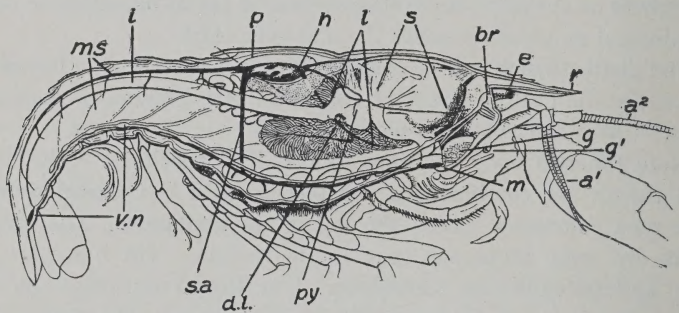


FIG. 6.—Internal anatomy of the crayfish. a^1, a^2, Antennæ; *br*, brain; *d.l.*, duct of liver or pancreas; *e*, eye; *g*, green gland with opening at g^1; *h*, heart; *i*, intestine; *l*, liver; *m*, mouth; *ms*, muscles; *p*, pericardium; *r*, rostrum; *s*, stomach; *sa*, sternal artery; *v.n.*, ventral nerve cord. (*From Hatschek and Cori.*)

Draw a diagram of the internal anatomy of the crayfish. Make the drawing very light at first and have it inspected before finishing it. Label it completely. It is sometimes advisable for students who have had little experience in drawing to use a stencil or some other device to get a perfect outline of the body in which to draw the visceral organs.

The **blood vessels** need not be looked for unless the specimens have been injected. The **nervous system** will be found by removing the other structures in the cavity of the body and looking first in the head between the eyes where the **brain** may be seen. What is its color and shape? Show it to the instructor. **Commissures** run back from it to the ventral ganglia going on either side of the esopha-

gus. Carefully dissect the tissues of the floor of the cephalothorax, and as you do so, trace the **nerve cord** back to the tail. Note that it is a double row of ganglia. Is there a double ganglion for each somite? See figure 95 in Atwoods' Biology and note the nerve cord of the earthworm. The crayfish has the same type as does the grasshopper and all other arthropods.

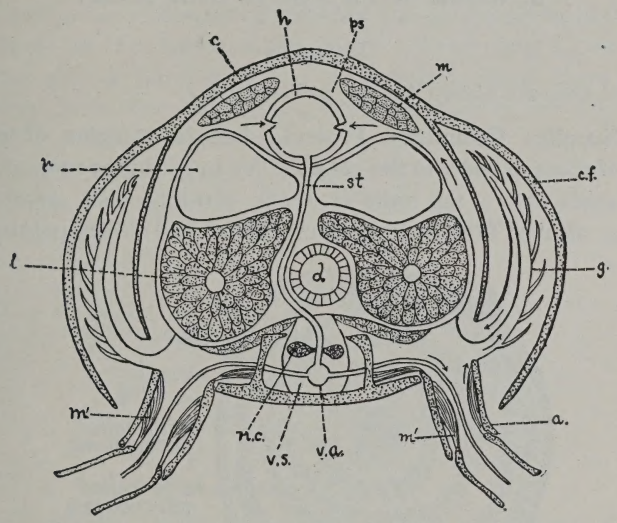


FIG. 7.—Diagramatic cross section through the thorax of the crayfish. *a*, Appendage; *c*, carapace; *c.f.*, flap of the carapace overhanging the gills; *d*, digestive tract; *g*, gills; *h*, heart; *l*, liver or pancreas; *m*, *m'*, muscles; *n.c.*, nerve cord; *ps*. space around the heart (pericardium); *r*, reproductive bodies; *st*, sternal artery; *v.a.*, ventral artery; *v.s.*, ventral blood sinus around the nerve cord. (*After Lang, Elementary Zoology, Galloway.*)

The **gills** of the crayfish lie in a row along the sides of the cephalothorax without the body-cavity but within the cover of the carapace. They have three different attachments and are in sets of one, two, and three for each somite. Can you determine where they are attached and which somites have three gills and which less?

The **ear** of the crayfish is to be found in the base of the antennule of each side. It is shown in Fig. 119 of Atwood's Biology and is more properly called a **statocyst.** Why? Cut it open and examine the interior. The picture was made from the lobster. Does it differ from the statocyst of the crayfish?

20. Project.—Try to keep some crayfish alive in the laboratory. They should be in charge of a student or committee, and should be fed twice a week or oftener. Do not permit stale food to remain in their water. Provide something for them to hide under.

8. WORK WITH ROOTS AND SOILS

Reference

Civic and Economic Biology, Atwood, Studies 7 and 8.

21. Supplies Committee Project.—Secure samples of various kinds of roots to show to the class. Try to get **brace roots** of corn; **aerial roots** of ivy; **tap roots** of weeds, turnip, radish, carrot, beet, parsnip, alfalfa; **fascicled roots** of dahlia, and sweet potato; and

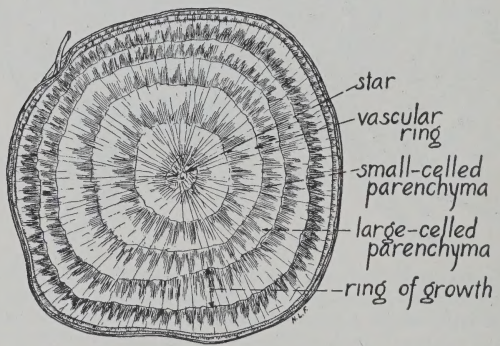


FIG. 8.—Diagramatic cross section of beet. (*Botany of Crop Plants, Robbins.*)

fibrous roots of various grasses and grains. As each specimen is presented to the class such points of interest as are known may be mentioned. **Drawings** may be made of some of them.

22. Project.—Two boys may secure a draw-scale and go out and pull up various weeds with it attached to their stems and note what force is necessary to remove them from their anchorages. A large scale will be necessary if you remove big weeds. Bring the weeds and the record before the class.

23. Laboratory Work.—Each student may be provided with sections of the carrot, beet, and other roots. Find the **epidermis,**

cortex, and **stele.** Note how the branch roots come off from the stele. Scrape some of the tissue of the carrot stem and examine under a compound microscope to find the various kinds of cells, especially the spirals of the sap ducts, of which the root is composed.

Draw a cross section of the root and label all of the parts.

24. Plate Gardens.—Some of the students may prepare some glass plates and pieces of blotter of the same size as the plates and plant small seeds on the surface of the blotter. Then place a glass plate on either side of the blotter and tie a string around them. Dip the plates and blotter in water and keep in a covered dish to prevent

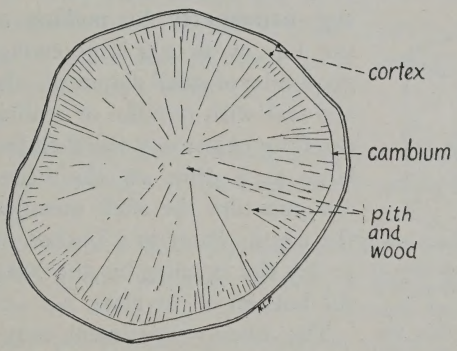


FIG. 9.—Diagramatic cross section of turnip. (*Botany of Crop Plants, Robbins.*)

evaporation. As the seeds grow the root hairs are seen. Plant different kinds of seeds in each garden.

Note.—Radish seeds are very easily germinated and develop root hairs which are of the best quality for observation. If sprays of the wandering jew (*Tradescantia*) are placed in water, they will develop excellent root hairs and tips.

25. Acid secretion of roots may be shown by letting seedlings spread their roots in soil over the surface of polished marble slabs or blocks. After some weeks they should be taken up and the slab cleaned, when a delicate etching may be seen on the polished surface. Another method is to prepare a fluid (thin) solution of gelatin and litmus. Add enough soda to make it slightly alkaline. Place it in a test tube and insert the roots of a seedling. Where the roots

secrete acid the litmus will turn red. Care must be taken to avoid the growth of bacteria before the demonstration is complete.

26. Individual Project.—Some of the students may plant the seeds of squash or pumpkin in sand. When the seedlings are the size shown in Fig. 45, Atwood's Biology, they may be pulled up if the sand has been allowed to become nearly dry, and the root hairs will hold the particles of sand as shown in the figure. Show your results to the class. This may be tried with other kinds of seeds. What is the value of root hairs to the plant?

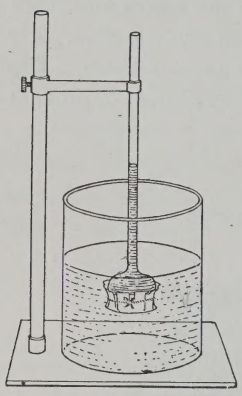


FIG. 10.—Apparatus to show osmosis through a membrane. Sugar solution is placed within the thistle tube and water is placed in the large vessel. (*Experimental General Science, Clute.*)

27. Osmosis Experiments.—Prepare an egg osmometer by making an opening in the top of an egg large enough to insert a glass tube of small diameter. Insert the tube and seal with paraffin or sealing wax. Now carefully chip away the shell from an area as large as a dime on the other end, but do not puncture the shell membrane. Emerse the egg in water in a beaker. It is best not to let the opening in the lower side touch the bottom of the glass.

The above experiment may be modified as shown in Gager's *Fundamentals of Botany*, Fig. 44. A further modification is to place the entire egg in a weak acid solution (about 4 or 5 per cent) as the shell is dissolved off the egg membrane becomes distended until the egg is nearly spherical.

28. The **carrot osmometer** is made by boring a hole in the top of a carrot (or beet) with an auger and fitting a rubber stopper in the opening. If the opening is filled with a strong sugar solution and the carrot is emersed in water good results should follow. Make more than one. See Atwood's Biology, Fig. 46.

29. Cell turgor may be demonstrated by placing slices of beet in strong salt water. Why do they become flabby. Place wilted slices in water. Why do they become turgid?

30. Individual Project.—Choose two plants which are easily wilted. Allow the soil in their pots to become dry. When they

are wilted, water one pot abundantly and cut the other plant off near its root and put it in a vase of water. Which revives the more rapidly? Of how much value are the roots and their root hairs?

31. **Soils.**—The **supplies committee** should secure samples of **sand, clay, humus,** and such other kinds of soils as are available and prepare an exhibit for the class. Another exhibit may be made to show the kinds of **rocks** which produce sand, clay, and limestone soils when they weather.

32. **Demonstration.—Hygroscopic water** may be shown by placing some soil in the bottom of a test tube and holding it in a horizontal position over a flame so that the soil is heated. Moisture will collect on the cool sides of the top of the tube. Compare the amount of such water in sand and humus. Is it possible that some of the water which comes from the humus is due to chemical decomposition?

33. **Experiment.—The value of a mulch** in conserving soil moisture may be shown by working out the experiment shown in Fig. 48 of Atwood's Biology.

34. **Capillarity** may be demonstrated for soils by placing various kinds in large glass tubes (gas lamp chimneys) which have been set up in pans. The soil will lie against the bottom of the pan. Pour water into the pans and watch it rise in the soil in the tubes. Which kinds of soil allow water to pass up the most rapidly?

35. **Percolation** may be demonstrated with the same apparatus as is used above, but the water is poured into the top of the tube in each case. Does it pass down equally fast in all soils. What soils will receive the most rain water?

36. **Project.—The humus content of soils** may be demonstrated by weighing out a small amount of dried soil on a delicate balance and heating it to redness until all of the carbon of the humus is burned out. On weighing again the difference in weight will indicate what proportion was composed of plant and animal remains. This experiment may be performed by various students as a project and the results presented to the class.

37. **Project.—The comparative ability of soils to hold water** may be demonstrated by the experiment shown in Fig. 48 in Atwood's Biology. Place a different kind of soil in each dish and

omit the sawdust. Do all soils dry out with the same rapidity? Show the results to the class.

38. Topic.—The fixation of nitrogen in soils by the agency of bacteria. See Fig. 21.

39. Crop Rotation.—Consult references and learn what this means. What has clover and other legumes to do with it? What would be a good rotation for a potato farm? For a farmer who specializes in wheat? In corn? In cotton? Make a diagram of each of the above mentioned rotations on the board. Discuss them in class and let each student make a copy for his notebook when they have been corrected. This may be worked out as a class project. The date of the study in class should be set two days ahead and each student should be given references in the agriculture texts in the library.

40. The value of drainage may be shown by placing plants in each of two tin cans. Make holes in one and leave the other as it is. Water them both frequently but keep the can without holes in the bottom flooded. After some days note the difference in the two plants. How long does the one without drainage live? Are all plants affected the same? How does excess water damage roots?

9. PLANT STEMS AND FORESTRY

References

Experimental Botany, Payne, American Book Co.
Civic and Economic Biology, Atwood, Studies 9, 10, and 11.

41. Field Trip.—Go to a woods or a park and study **trees.** Learn to recognize them by the shape of their stems and branches. Compare the thickness and roughness of the bark. Note also its color. Compare the **twigs** as to size. Collect samples of twigs to show various kinds and arrangement of buds, and bring them to the laboratory. Place some of the **buds** which have been collected after the leaves have fallen, in water in the warm sunlight. They will open and may be studied as to their **scales, scars, leaves** and **flowers.**

42. Draw specimens of buds and label them. See Figs. 55, 56, and 57 in Atwood's Biology.

43. Demonstration.—The **supplies committee** should secure specimens of **erect, climbing, prostrate,** and **underground stems** and present them to the class with appropriate remarks as to where they are found, how they are related to the environment of the plant, and what special advantages each provides.

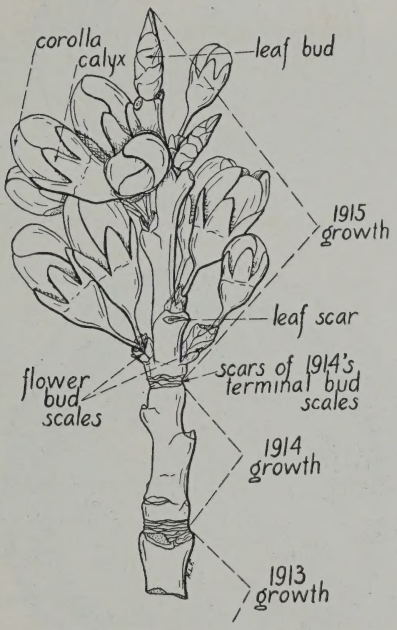


FIG. 11.—Spur of sour cherry to show flower buds. Compare with Figs. 55, 56, and 57 in Atwood's Biology. (*Botany of Crop Plants, Robbins.*)

44. Notebook Work.—Prepare a table listing the advantages and disadvantages of each special kind of stem.

45. Project.—Plant specimens of bulbs, corms, tubers, and rhizomes. Give them into the charge of a committee and observe them from time to time throughout the coming months.

46. Draw cross sections of **young stems** and label the regions and rings of tissues which appear. Permanent slides may be had from dealers. These may be used with the microscope or lantern.

47. Experiment.—Investigate the circulation of sap in stems by placing various kinds in red ink. They should be in good health

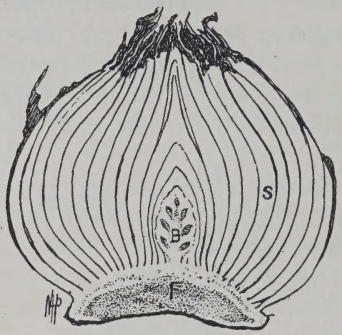


FIG. 12.—Section of tulip bulb to show the structure of a typical bulb. *B*, Flower bud; *F*, stem; *S*, bud-scales. (*Fundamentals of Botany, Gager.*)

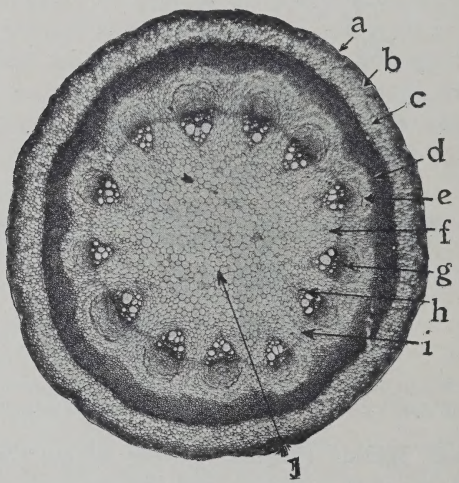


FIG. 13.—Photomicrograph of a cross section of a young stem of *Aristolochia sipho* to show beginning of the formation of the cambium ring. *a*, Epidermis; *b*, collenchyma; *c*, parenchyma of cortex and starch sheath; *d*, sclerenchyma; *e*, thin-walled parenchyma of the pericycle; *f*, medullary ray; *g*, phloem; *h*, xylem; *i*, cambium; *j*, pith. (*Plant Anatomy, Stevens.*)

and growing. The ink will pass up in their sap ducts making them more easily seen. In what part of stems does the sap flow up?

Draw cross sections of stems to show the region where the sap flows upward.

48. Project.—Plant portions of stems of the willow, English ivy, and other plants with their top ends in the soil and the bottom ends up. If they are well cared for they will grow this way. What influence do you think gravity has on the direction of flow of sap?

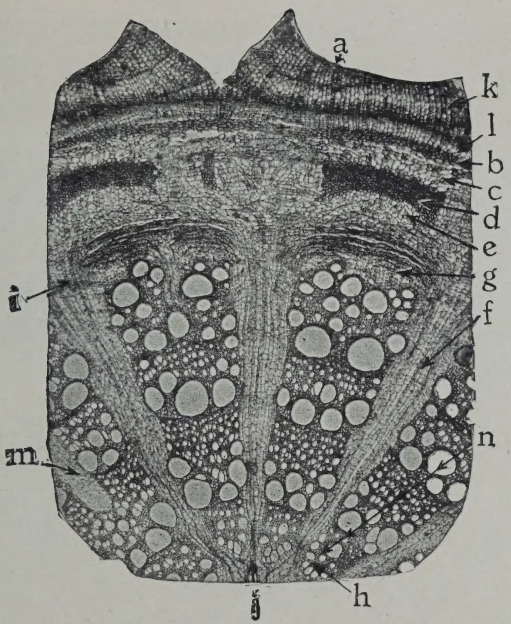


FIG. 14.—Photomicrograph of a cross section of a four-year-old stem of *Aristolachia sipho.* Note the annual rings and the compressed medullary rays. The labeling is as in the previous figure with the following additions: *l*, Cork cambium; *k*, cork; *m*, new medullary ray forming; *n*, from this point out the xylem has been formed from the cambium. (*Plant Anatomy, Stevens.*)

49. Reports and Topics.—Will the **library committee** prepare a list of topics on trees and forestry which are suitable for written themes or reports? The **archives committee** will consult with the instructor when the topics selected are written up and choose those which should be given to the class.

50. Demonstration.—Show specimens of **plane** and **quarter sawed oak** and other woods to the class and explain the grain

of wood. It is due both to the **annual rings** and the **medullary rays.**

51. Project.—Find some **stumps of trees** which have been cut recently, measure their diameters, and count their rings. How fast do trees grow? Compare the speed of growth of hard and soft woods. Report your findings in class.

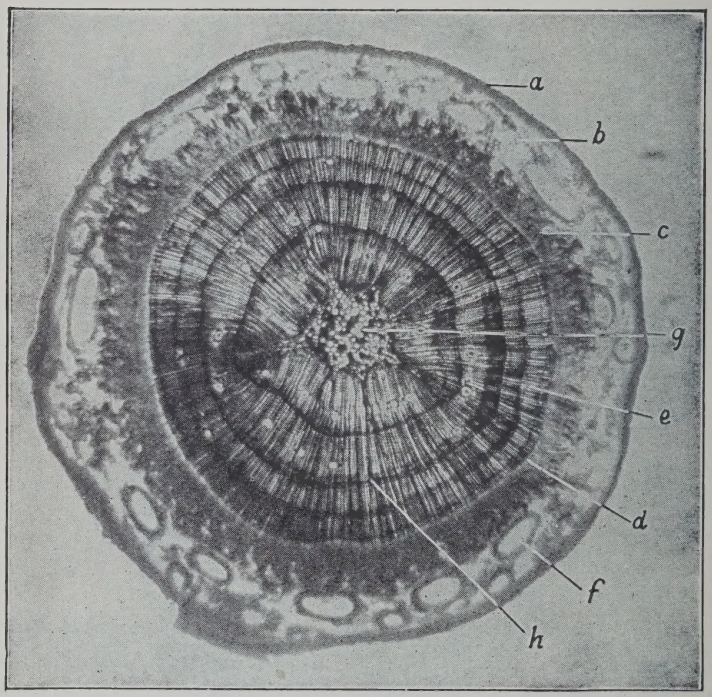


FIG. 15.—Transverse section through a four-year-old stem of white pine. *a*, Cork; *b*, cortex; *c*, phloem; *d*, cambium; *e*, xylem; *f*, secretion reservoir; *g*, pith; *h*, medullary ray. (*Pharmaceutical Botany, Youngken.*)

52. Demonstration.—The **museum committee** should prepare an exhibit of specimens of wood which are **ring porous, diffuse porous,** and of evergreens which have **resin ducts** instead of pores. If no specimens are in the laboratory, try to secure some. They will show their special features better if they are planed and polished in the department of manual training.

53. Committee Investigation.—Learn what trees are favored for street planting in your city. Why are they favored? Make a list of our native trees which are good for city planting and a list which are not. Give reasons. Present the results of your investigation to the class. For the above information you should visit the city forester or the city clerk.

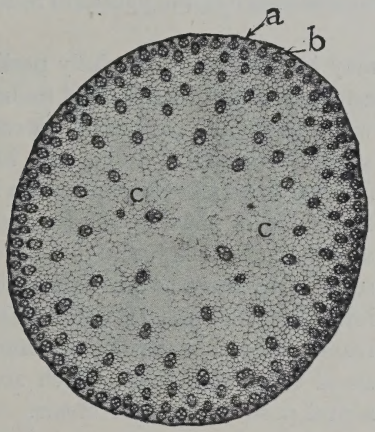


FIG. 16.—Photomicrograph of a cross section of a corn stalk to show the parts of an endogenous stem. *a*, Epidermis; *b*, cortex and pericycle; *c*, fundamental (pith) tissue with vascular bundles interspersed in it. The large tubes of the bundles are xylem, the small tubes are phloem. (*Plant Anatomy, Stevens.*)

10. THE STRUCTURE AND WORK OF LEAVES

References

Civic and Economic Biology, Atwood, Studies 12 and 13.
Experimental Botany, Payne, American Book Co.
Plant Anatomy, Stevens, P. Blakiston's Son & Co.

54. Types of leaves may be studied by having each student bring as many kinds as he can find to class. When collected, they may be sorted into three groups—those of the **conifers, palmate,** and **pinnate** leaves.

Note the shape of the **needles** of the pines and spruces. Fir needles are flattened, spruce needles are square in section, and pine

needles are long. The foliage of the hemlock, arborvitæ, juniper, and cypress should be studied so that it may be recognized at sight if these trees grow in your locality.

The **pinnate** leaves may come from trees, shrubs, and herbs. Sort them into their various types. Do the same with the **palmate** leaves.

55. Draw some of the leaves which have been brought in and label them with the assistance of the figures in Study 12 of Atwood's Biology.

56. Stomates may be studied by carefully peeling the epidermis from the lower surface of various leaves and mounting in a drop of water under the compound microscope. An onion stem, the leaves of tulips and lilies, and the live-for-ever have an epidermis which is easily removed. Some leaves may be viewed as opaque objects, and if the light is just right, the stomates may be seen. Are there as many on the upper as on the lower sides of the leaves? Can you think of a reason for this variation? Compare leaves which stand erect with those which are held in a horizontal position on their stems.

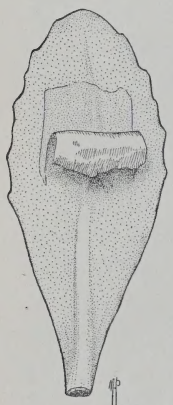


FIG. 17.—Leaf of the live-for-ever with a portion of the epidermis peeled to show the method of removing the epidermis to view the stomates under the microscope. (*Fundamentals of Botany, Gager.*)

Draw some stomates as you see them under the microscope. See Atwood's Biology, Fig. 78.

57. Topics.—How do stomates open and close? Why do they do this? What gases and vapors pass in and out through stomates? Of what value to the plant is this interchange?

58. Notebook Work on Photosynthesis.—Consult the following biologies and write a description of photosynthesis: Atwood, Fig. 80; Hunter, p. 106; Moon, Fig. 26. Answer the following questions. What organs of the plants perform this work? What energy is used? What materials? What are the waste products? What are the products of this action and what is done with them? Why is starch called a carbohydrate? Design a diagram to illustrate your topic.

59. Transpiration.—Split a cork lengthwise in two parts, and hollow out a groove in each half to fit the stem of a plant. Pull the

plant out of the soil with its roots in good condition. Wash them. Fit the halves of the cork around the plant stem near the roots and put the roots in a test tube of water which will hold them. Fit the cork in the mouth of the tube. Now insert a fine glass tube in the side of the cork so that air may pass into the test tube, and then seal the cork and plant in with chewing gum, paraffin, or vaseline. Weigh the plant and tube carefully and place in the sunlight.

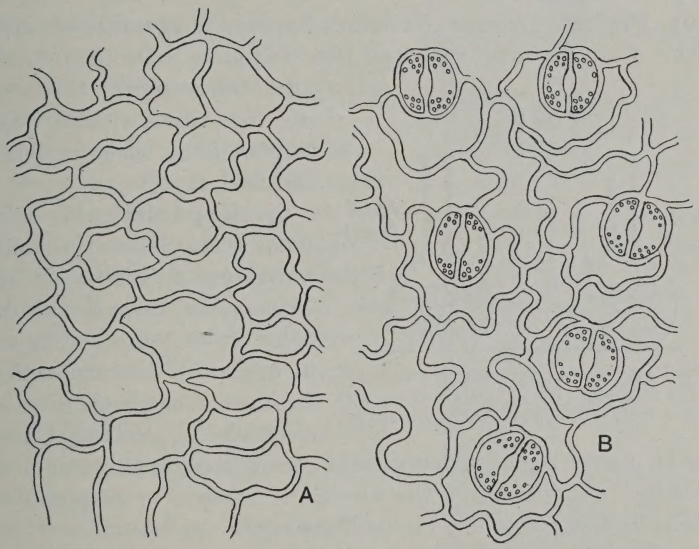


FIG. 18.—*A*, Upper epidermis without stomates; *B*, lower epidermis with stomates of the fern *Drynaria meyeniana*. (*Heredity and Evolution in Plants, Gager.*)

Weigh again from day to day. The only way in which the test tube can lose water is through the plant, as that which comes out through the glass tube is negligible. Make more than one of these experiments and compare.

60. Projects.—Consult references and set up some of the many experiments which have been designed to **illustrate transpiration.** Which demonstration is the best?

61. Diffusion of gases may be illustrated by the instructor as is shown in the figure.

62. Guttation drops may be obtained by using the split cork and test tube described in the experiment above. Place a large leaf in the tube, rolled up if necessary, and seal it in. The leaf should be of a plant which gives off much water. The geranium is not good for this demonstration. See Fig. 81 in Atwood's Biology. Try some other methods also. When does water come out of the water pores in leaves? Do all plants have them? Are guttation drops the same as dew?

63. Project.—Arrange for a committee to **plant some seeds in the dark.** Care for them well, and they will grow. Do they develop any chlorophyll? How long do they live without light? Report from time to time to the class.

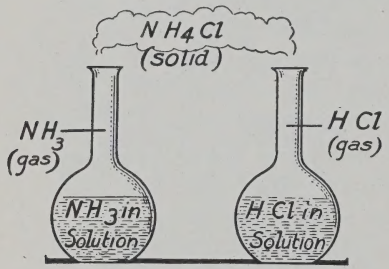


FIG. 19.—An experiment to show diffusion of gases. How does air enter and leave a leaf? (*General Science, Brownell.*)

64. Experiment.—Place some green leaves in boiling water for a minute or two. Then place them in alcohol. After a time they will be seen to have lost their **chlorophyll.** Remove them and note the color of the alcohol. Chlorophyll is a green pigment composed of a protein containing iron in the "ferrous" condition. If the alcohol is allowed to evaporate the chlorophyll will remain. Is it still green?

65. Projects.—Make **skeleton leaves.** See Payne's Botany, p. 146.

Make **blue prints of leaves.**—See Payne's Botany, p. 146.

66. Demonstration.—Set up the apparatus shown in the illustration and collect **oxygen** in the test tube which is placed over the funnel. Common ditch moss (*Elodea*) or some other plant which lives in water will do. This experiment does not work as easily as some manuals would lead the experimenter to believe. It must be in bright sunlight, and when the carbon dioxide in the water is all gone it must be given time to collect from the air, or it may be made from limestone and acid and bubbled in. How is this experiment related to photosynthesis? See Payne's Botany, p. 162.

67. Microscope Work.—Chloroplasts may be seen in green cells with the compound microscope. Secure some spirogyra (See Fig. 184 in Atwood's Biology) or some ditch moss (*Elodea*) and place it under the microscope in a little water. Do not get any water on the stand of the microscope or on the lenses. Note that the chlorophyll is confined to definite bodies within the plant cell. They are bands in spirogyra, and rounded bodies in *Elodea*. If these plants are not available, various other green plants will do. Draw what you see and label as completely as you can.

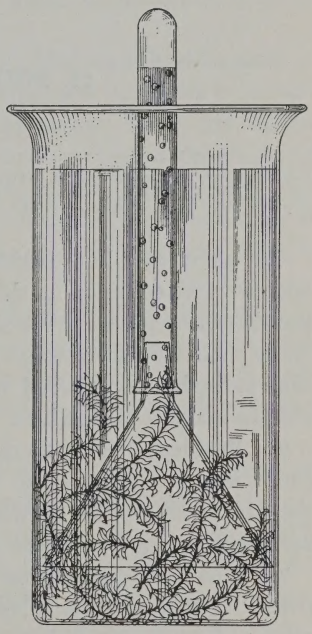


FIG. 20.—Apparatus for showing that oxygen is a byproduct of photosynthesis. (*Palladin's Plant Physiology, Livingston.*)

68. Teacher's Demonstrations.—To Show that Plants Need Oxygen. Follow directions as given at the bottom of p. 96 in Atwood's Biology.

To Show that Plants Need Carbon Dioxide.—Repeat as above but put in a dish of pure sodium hydroxide or lime water. The dishes used in these demonstrations should be wide across and shallow. Some plants will live a long time under the above conditions.

69. Demonstration.—Sap circulates through the veins of plant leaves. Prove this by placing various leaves and seedlings with leaves in red ink so that it will be absorbed by the leaf stem or the roots of seedlings and sent out into the leaves. Note that the veins become red. A concentrated solution of ink will be too strong. It should be diluted. It may take one or two days to complete this demonstration.

70. Experiment to Demonstrate the Presence of Starch in a Green Leaf.—Pluck a leaf from a geranium of the kind which has white markings on its leaves, and which has stood in bright sunlight for about two hours. Place it in boiling water at once.

Treat it with alcohol as directed above in studying chlorophyll. This is to get the color out. When the leaf is no longer green, place it in a solution of iodine for an hour or more, if necessary. The blue color denotes starch and its absence in the places which had no chlorophyll indicates that it is produced in the green tissue only.

11. FOOD AND ITS USES

References

Civic and Economic Biology, Atwood, Studies 14, 15, and 16.
A Civic Biology, Hunter, Chaps. XIX and XX.

We have seen how plants secure their food by photosynthesis, and we will consider in the work which follows some of the food problems of animals. We should keep in mind the fact that plants make their food from water, carbon dioxide, and mineral salts; and that animals use the food which plants have elaborated not being able to make it themselves.

71. Problem.—How do molds get their food? Place some moist bread in a covered dish so that it will not dry out and keep it in the dark. Does mold need sunlight? Has it chlorophyll? Does it use the same foods as green plants?

72. Dissolve some glucose or corn sirup in water and add some **yeast.** Put it away in a warm place in the dark. Does the yeast grow? Compare it with a mold in its food-getting.

73. Notebook Work.—Write an article on the food-getting of green plants as compared with yeasts, molds, and bacteria. The archives committee will select a few of the best to be read to the class.

74. Euglena.—It may be possible to get some euglena from a pond. If not, they may be had from Powers & Powers, Station A, Lincoln, Nebraska, or from some other dealer. Observe them under the microscope. How do they move? Can they swim? If so, how? Note that they are green. This is due to chlorophyll. They live like a plant, and have the advantage of being able to go from place to place.

Draw several euglena in different positions. Can you show the **nucleus, eye spot,** and **gullet?** It will probably not be possible to see the **lash.**

The author has kept a culture of a green protozoan, resembling the euglena, in an aquarium in the laboratory for several years. Try to make a culture of euglena. Place it in the charge of a committee.

75. Notebook Work.—Animals are divided into **herbivorous** or **carnivorous** groups according to whether they eat vegetable or animal food respectively. Some, as man eat both. They are called **omnivorous.** Make a table of the vertebrate animals assigning them to one or the other of the three classes. Bears and dogs are carnivores in spite of the fact that they eat large quantities of vegetable food. Discuss all doubtful cases before placing them in the table.

76. Project.—Make several balanced aquaria and place each in charge of a student. Observe them from time to time as the plants and animals grow. Do they all stay balanced? See Atwood's Biology, Figs. 86, 87, and 356. See also Hunter, p. 166; Hodge and Dawson, p. 13, 299, 315.

77. Notebook Work.—Consult some of the following references and **make diagrams of the chemical cycles listed below:** Atwood, Figs. 9, 82, and 86; Gruenberg, Chap. XIV; Moon, Chap. LIII; and Hunter, Chap. XIV. Diagram the **carbon cycle** first, then the **nitrogen cycle,** and then the **food cycle.** Use a ruler and compass in drawing your lines so they will be uniform and neat. If time permits, it will be well to write notes explaining each diagram.

78. Food Plants.—See p. 102, Atwood's Biology, and make a table of the common plants which are used as food. In each case we use the **roots, stems, leaves, flowers, fruits, or seeds.** Assign each plant to its proper place in the table. It may be well to work this table out on the board as a class project, after which it may be copied in the notebooks.

79. Caloric values of foods have been overstressed of late years. If it is desired to do such work, a reference may be consulted. See Atwood's Biology, p. 107.

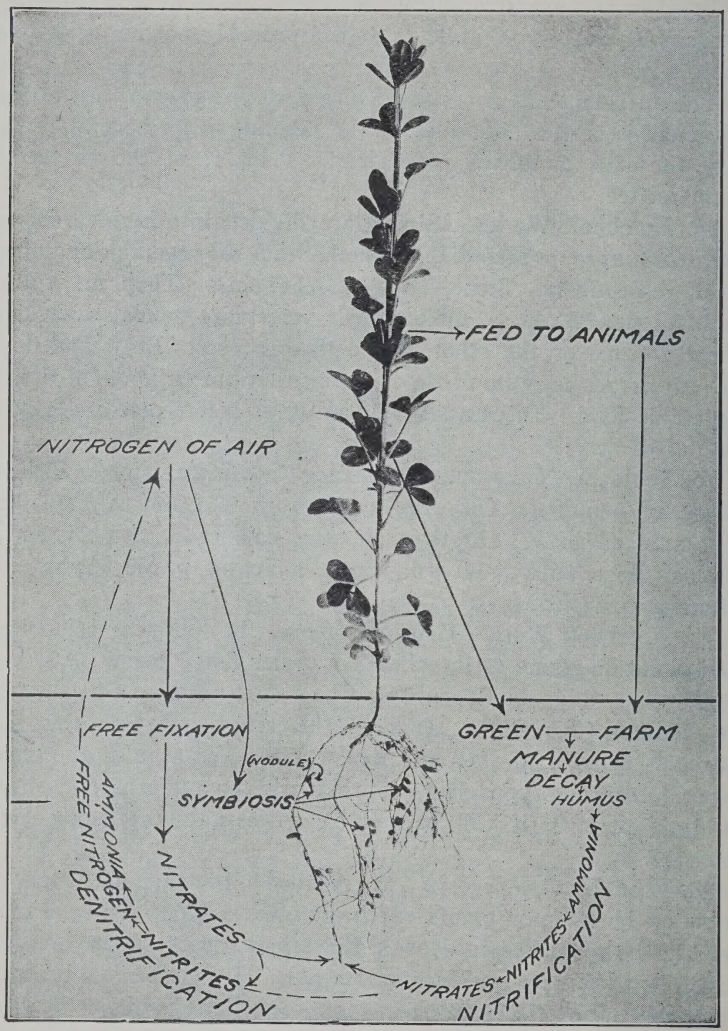


FIG. 21.—The nitrogen cycle as shown in the life of an alfalfa plant. (*General Science, Brownell.*)

80. Topic.—Insectivorous plants capture insects and digest them. Pitcher-plants, sundew, and the Venus fly-trap are described and illustrated in *Interesting Neighbors,* Jenkins, P. Blakiston's Son & Co.

FIG. 22.—The Venus fly-trap, the leaves of which capture insects for food. (*Heredity and Evolution in Plants, Gager.*)

Compare the food-getting of these plants with other plants and animals. In what situations do they live? Is their habitat lacking in essential plant foods?

12. CHEMICAL FOOD TESTS

Reference

Civic and Economic Biology, Atwood, Studies 14, 15, and 16.

The following tests may be made by each member of the class if laboratory facilities permit; or they may be performed as a demonstration from the lecture table. Each should be written up carefully in the notebook. See Atwood, Study 15; Hunter, the last half of Chap. II; and Payne's Botany, pp. 19–29.

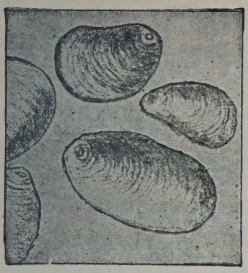
81. Carbon Test.—Place bits of cloth, wood, feathers, etc., in small test tubes containing small amounts of concentrated sulphuric acid. The acid decomposes organic compounds and extracts water leaving the carbon to color the contents of the tube black. It may be necessary to let some tubes stand for quite a while.

82. Starch Tests.—Starch is not soluble as it exists in plants, therefore it will be necessary to boil some starch in a test tube of

FIG. 23.—Starch cells of a potato before and after being cooked. Describe what has happened. (*General Science, Brownell.*)

water. Cool it. Add a few drops of a solution of iodine. The starch is changed to starch iodide which is blue. Heat it, the solution should be clear. If it is cooled again, the blue color returns. Iodine may be dissolved in water if a few crystals of potassium iodide are dissolved first. This is better than an alcoholic solution. Test various foods for starch. Is there any starch in sugar? In corn sirup? In honey? In mucilage?

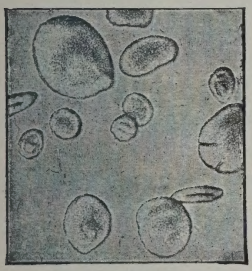
Scrape a raw potato and place some of the pulp under a compound microscope. The **starch grains** have an appearance somewhat like



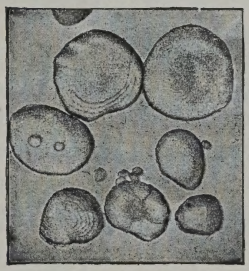
Potato.

Bean.

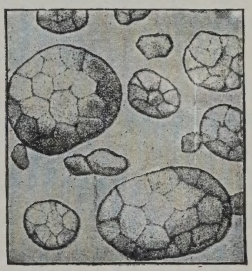
Arrowroot.



Rye.

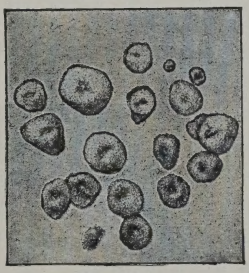


Barley.



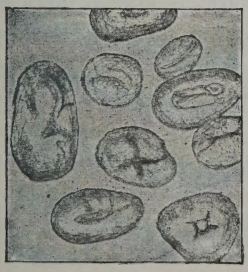
Oat.

Buckwheat.

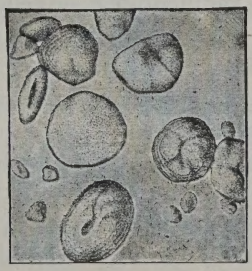


Maize.

Rice.



Pea.



Wheat.

Fig. 24.—Various types of starch grains as seen under the microscope. (*Food Analysis, Leffmann and Beam.*)

an oyster shell. Grains of starch from different plants have a different appearance. Examine several kinds in water. Can you tell from what plant a sample of starch came by examining the grains? Can you tell if potato starch has been mixed with corn starch?

83. Glucose Test.—When a solution containing glucose is heated with Fehling's solution the copper in the test fluid is oxidized by the glucose, and yellow to deep orange copper oxide appears in the test tube as a precipitate.

Fehling's solution may be made as follows: Dissolve 34.65 grams of copper sulphate in 500 cc. of water and put in a bottle. In another bottle containing 500 cc. of water dissolve 125 grams of sodium hydroxide and 173 grams of Rochelle salt (sodium-potassium tartrate). Keep the solutions separate until shortly before they are to be used when they are mixed in equal parts to form Fehling's solution.

Heat a dilute mixture of glucose and Fehling's solution in a test tube. Note the beautiful deep orange to red color. Try this with various foods, especially cane sugar, starch, mucilage, and flour.

Place some ground cracker, flour, or starch in water and add some **diastase** or **saliva.** After a few minutes test with Fehling's solution. What is the action of these two ferments on starch?

84. Protein Tests.—Prepare some white of egg in water.

1. The **heat test** is made by placing some of the solution in a test tube and boiling. A cloudy appearance indicates the presence of a protein which coagulates when heated.

2. The **xanthoproteic,** or **yellow test,** is made by placing nitric acid on some egg white in the test tube and heating gently. It should turn yellow. Now pour out the excess liquid and add enough ammonium hydroxide to neutralize the acid. A deep orange color should appear.

3. The **burning test** is made by burning a piece of meat or a feather and noting the odor.

4. The **sugar test** is made by adding a drop of concentrated cane sugar solution to the protein solution in a test tube and then adding a drop or two of pure concentrated sulphuric acid, when a deep red color appears.

(**Millon's test** and the **biuret test** give a red and a violet color respectively. They may be found described in Hawk's Physiological Chemistry, and Payne's Botany. They are both very delicate tests.)

Apply some of the tests described above to various kinds of foods.

85. Fat and Oil Test.—Foods which contain much oil will make a grease spot on paper. It may be necessary to grind the material very fine and press it against the paper. A gentle heat may be of some aid. Be sure that the spot is not a water spot by giving it time to dry or by warming it. If it is an oil spot it will stay.

Soudan III may be had from the dealers. It is a dye. Place it on the grease spot and then wash the spot with alcohol. Note the color.

86. Water or Moisture Test.—Place some of the material to be tested in a test tube and hold in a horizontal position over a flame so as to heat the material in the bottom of the tube without heating the top of the tube. If moisture is present, it will collect on the sides of the tube. If the material is strongly heated the moisture may result from the chemical decomposition of the substance which is tested.

87. Test for Mineral Matter.—This is sometimes called the ash test. Heat the material to be tested in a crucible until it is red. Keep it so for a long time. If anything remains it is mineral matter which will not burn or pass off as a vapor.

Free salts in a soluble condition may be detected by soaking the material to be tested for a time in water and then filtering the water and allowing it to evaporate, when they will be left as crystals.

88. Review.—How can you detect starch in pulverized sugar? Starch in glucose? Salt in meat? Starch in ice cream? Glucose in candy? Starch in candy? Wool from cotton? Salt in butter? Limewater in milk to keep it sweet? Barley flour in wheat flour? Starch from flour? Glue from mucilage? If a dispute arises about any of these questions it should be tried out,—that is the proof.

89. Milk Tests.—**Sour milk** may be tested for by placing a strip of blue litmus in it. If the litmus turns red, the milk is sour. Another test is to put some soda in the milk. If it effervesces, the milk is sour. Explain the chemical action. Is sour milk used in

cooking? Explain. Smell and taste are also good methods of testing sour milk.

90. Butter-fat tests of milk are made by centrifuging the fat from the rest of the milk or dissolving out the fat in ether. **The Babcock milk test** is most frequently used, but the ether test is more accurate. Get State and Government bulletins from the agricultural departments which give directions for making the test. Also see Bowden's General Science, p. 574. The test may be made before the class as a demonstration. If we should give complete directions for making the test here, it would require too much space, as there are many difficulties to avoid.

91. The formaldehyde test is made by placing some milk in each of two beakers. To one add a small amount of formaldehyde and leave the other as it is. Place a drop or two of a solution of ferric chloride in some pure hydrochloric acid. Add twice as much of this acid to each of the beakers of milk as there is milk. Mix the milk and acid well by rotating the beakers. Place them both in boiling water for some minutes. The milk which contains formaldehyde becomes lavender to purple in color. Why is formaldehyde added to milk? To determine this take two samples of fresh milk and add a few drops of formaldehyde to one and none to the other. Set them away and observe which becomes sour first. *Formaldehyde is a dangerous poison*, and must not be used in preserving milk.

13. DIGESTION

References

Civic and Economic Biology, Atwood, Study 16.
Elementary Biology, Gruenberg, Chap. XIX.

92. Committee Project.—Dissect one or more frogs to show the digestive system. Spread the specimens under water in pans and show to the class. The organs may be drawn and labeled. Ward's, Rochester, N. Y. have a model of a frog which may be set up before the class and its organs drawn. Other preparations may be had of the specimens in glass jars with the organs dissected. The

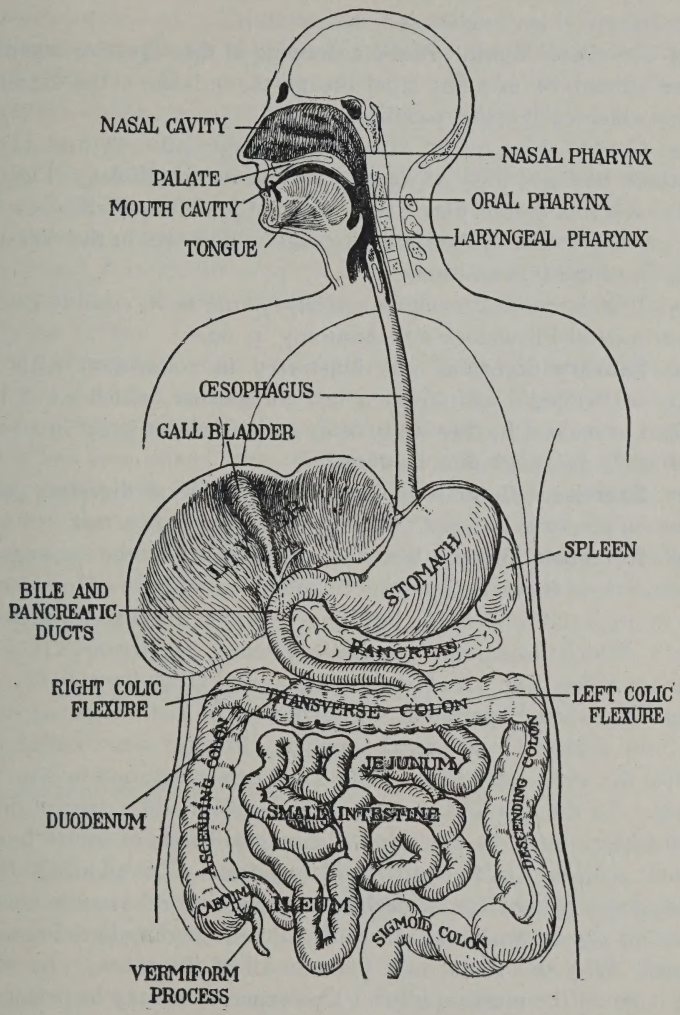


FIG. 25.—Diagram of the alimentary canal of man to show its parts. (*From Morris.*)

museum committee may make some preparations of various animals and preserve them in glass jars in formalin.

93. Notebook Work.—Make a drawing of the digestive organs of some animal, or of man; label the parts, and name the digestive juices which each organ supplies.

94. Consult Fig. 91 in Atwood's Biology; pp. 275 and 343 in Hunter's Biology; Figs. 28 and 32 in Gruenberg's Biology; Fig. 114 in Moon's Biology; or Figs. 178 and 165 in Smallwood's Biology and write a description of the similarities and differences in the digestive systems of the frog and man.

95. If it is desired to make a study of the *teeth*, consult Eddy's Experimental Physiology and Anatomy, p. 60.

96. Salivary digestion was illustrated in connection with the study of Fehling's solution as a test for glucose, which see if it is desired to make a further study of its action. Does it act in an acid medium? In an alkaline medium?

97. Exercise.—Commit to memory the table of digestive juices given on p. 112 of Atwood's Biology and write it as a test.

98. Notebook Work.—Write a description of the passage of digested food from the intestine to the blood system. How does it get through the walls of the intestine? Which foods go through the liver? Which through the lymphatic system? See Atwood's Biology, Fig. 93; Moon, Fig. 121; Hunter, p. 354; and Gruenberg, p. 87.

99. Digestion Experiment.—Pepsin may be had from drug stores or from dealers in biological supplies. Prepare some boiled egg. Mince the white very fine. Place some pepsin solution in four test tubes. To the first add nothing, to the second add a drop of dilute hydrochloric acid, to the third add several drops of dilute hydrochloric acid, and to the fourth add two drops of an alkali (NaOH). Place some minced egg in each test tube and stand away in a warm place for one or two days. In which of the tubes has digestion taken place? Why did it not take place in all of the tubes? In which did it go on the most rapidly? This experiment may be performed by each of four or five students and the entire class may view the results if time and space are limited. Write it up completely in the notebooks and state which tube was the most representative of the actual conditions which exist in the stomach.

100. Pancreatin may be used in a similar manner to illustrate intestinal digestion. The only place where fats are digested is in the intestine. If you wish to digest fats, use corn oil, cottonseed oil, or olive oil. The pancreatin must be fresh and of the best quality or results will be disappointing. It may be made alkaline by adding a little sodium carbonate.

101. An emulsion may be made to show to the class by mixing a light vegetable oil with a dilute alkali and shaking. Does the fat remain emulsified? For how long? **Soap** will form from this emulsion if it is left to stand or is warmed. An understanding of the chemistry of soap-making is helpful in understanding the digestion of fats.

102. Absorption.—Our problem here is, **why are foods digested?** Use two diffusion shells such as are sold by the dealers in biological supplies. Suspend each in a vessel of water. Place some **starch** which has been mixed with cold water in one and some **glucose** or **honey** which has been diluted slightly in the other. After some time test the water in the first vessel for starch. Test the water in the second vessel for glucose. Did the starch osmose? Did the glucose? Which digestive juices change starch into glucose? Why is this necessary?

14. RESPIRATION AND CIRCULATION

Reference

Civic and Economic Biology, Atwood, Study 17.

103. Teacher's Demonstration.—Secure some defibrinated (unclotted) blood from a butcher, or by killing a chicken, and put it in a bottle. Pass **carbon dioxide** through the blood rapidly from a generator. Note that the blood becomes a **deep purple** in color. Look at the veins in the wrist and compare. Now pass **oxygen** through the blood. It becomes a **bright scarlet.** Explain how carbon dioxide and oxygen are carried by the hæmoglobin in the blood. Why is the blood which flows from a cut always red?

Pass **carbon monoxide gas** through the blood and note that it becomes a **carmine red** in color. In dilute solutions it becomes a

bluish-red. Carbon monoxide has such a strong affinity for hæmoglobin that it can not be replaced by oxygen as can the dioxide. Does this explain why it is a deadly poison? Can the presence of carbon monoxide be detected by its odor? Why is it dangerous to be in a closed room with a gasoline engine running?

In the above demonstration, the carbon dioxide may be obtained by placing hydrochloric acid on lumps of limestone. The oxygen may be obtained from the air and may be pumped through with a bicycle pump. The carbon monoxide may be had by passing gas from the gas jet through the blood, or it may be made by placing concentrated sulphuric acid on crystals of oxalic acid in a generating flask.

The technical words used in this study should be carefully spelled on the board, and the experiment written up in the notebook.

104. The function of the diaphragm in respiration may be shown as in the figure. A piece of dentist's rubber sheeting may be tied over the bottom of the vessel. Place a button in its center and fasten a string around the button and the rubber. A toy balloon may be placed on the inside of the glass vessel. Write an explanation of this demonstration.

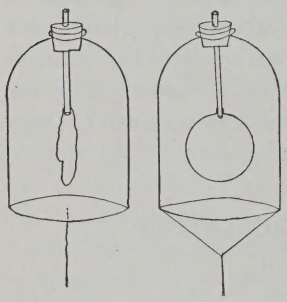


FIG. 26.—Apparatus for an experiment to show the effect on the lungs of depressing the diaphragm. (*Elements of Animal Biology, Holmes.*)

105. Notebook Work.—From a model of the heart, from charts, from illustrations in texts (*Atwood*, Fig. 99), or from a pig's heart **describe the circulation of the blood** through the heart.

The circulation of the blood of the earthworm may be described from Fig. 95, *Atwood's Biology*. A dissection to show these vessels may be made by some student as a project, but it is usually only a partial success as a class dissection. Put the dissected specimen in the museum case.

106. The operation of the tracheal system of an insect may be described from Figs. 33 and 96, *Atwood's Biology*.

107. Red blood corpuscles may be studied under the microscope as directed in *Eddy's Experimental Physiology and Anatomy*, p. 72.

108. The circulation of the blood in the frog's foot may be demonstrated as directed in *Eddy*, p. 79.

109. The Air in the Lungs.—Blow the breath gently on a piece of cold **glass** or metal. What collects on the surface of the glass or metal? Blow gently on the bulb of a **thermometer.** What happens? Blow slowly through a glass tube into a glass of fresh **limewater.** What causes the cloudy appearance of the limewater? Write a statement in your notebook telling what you have learned from these tests. When a **fire** burns what are the products? Compare with the statement which you have just written.

110. Project.—Two boys may weigh themselves very accurately before athletic practice and again after. What became of the materials which were lost? How is the energy of exercise furnished?

111. Lung capacity may be determined by filling a large glass vessel, as a bottle, with water either before or after inverting it in another and larger vessel of water. Insert a large glass or rubber tube under the vessel. After taking a normal breath the air from the lungs should be blown into the inverted glass vessel. A convenient scale of measurement should be applied to the side of the vessel. Now fill the lungs full to capacity and repeat. Compare with others. Sterilize the end of the tube which you put in your mouth. In the average student's lungs there will remain about 100 cubic inches of air after all has been expelled which can be driven out. What is your average lung capacity? What is your maximum capacity?

15. TROPISMS AND RESPONSES

References

Civic and Economic Biology, Atwood, Unit III.
Experimental Botany, Payne, American Book Co.
The Animal Mind, Washburn, Macmillan Co.

112. Projects.—**Geotropism** is the response of a plant to the force of gravity. It may be shown by the following methods. When they are ready they should be shown to the class by the student who has the project in charge. (1) Set up the apparatus as shown in Atwood's Biology, Fig. 103; also read p. 256 and set up the

apparatus of Fig. 221. (2) Perform the experiment shown in Payne's Botany, Figs. 39 and 40, and also in Moon's Biology, Fig. 10.

113. Hydrotropism.—Perform as projects the experiments shown in the references following and report to the class as they are ready. Atwood, Fig. 104; Moon, Fig. 11; Payne, Exps. 77, 78, 79, 80, and 81. See also Hunter, p. 73, and Gruenberg Chap. IX.

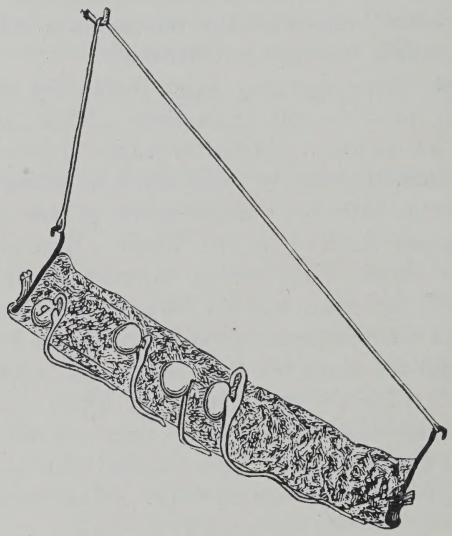


FIG. 27.—Apparatus for the demonstration of positive hydrotropism of roots. Must this attraction be stronger than gravity in this case? Use a wire basket and fill it with bog moss and sawdust. Keep it moist. (*Palladin's Plant Physiology, Livingston.*)

114. Phototropism.—Refer again to the experiment where a plant was placed in the dark with light admitted through an opening (Fig. 1). Also to the compass plant Fig. 108 in Atwood's Biology. The rex begonia is an excellent plant to show phototropism. It is shown in Fig. 8, Atwood's Biology. See Moon, p. 88; Hunter, p. 100, and Gruenberg, Chap. IX. **Heliotropism** is another word for phototropism.

115. Thigmotropism may be demonstrated before the class by touching the leaves of the sensitive plant, and by touching an earth-

worm or a frog with a bristle. Touch the animals in various places and determine if they are equally sensitive in all parts of their bodies.

116. Thermotropism, with its minimum and optimum effects, may be shown by preparing a trough as shown in the illustration and placing in it some water inhabiting animals. The temperature of the warmed end should not get above 98°F., and the temperature of the end which is cooled with ice will be about 34°F. The partitions should go to the bottom and may be held in place with sand. They are to prevent convection currents from warming the entire trough,—or cooling it. Place a thermometer in each compartment

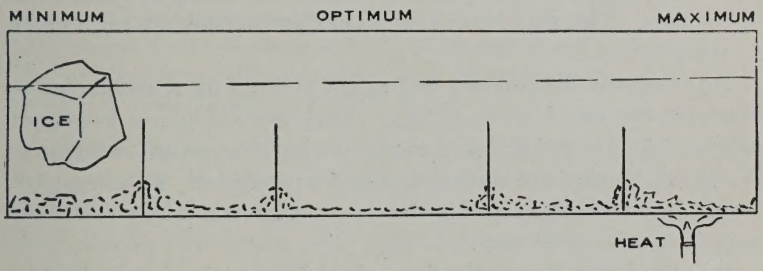


FIG. 28.—Diagram of a tank to show how animals seek optimum conditions in which to live.

and record the temperatures on the board. This demonstration should be started about two hours before it is to be shown to the class. There will be considerable difference in the results obtained with different kinds of animals. The more active they are the sooner they will respond.

117. Trial and error reactions may be observed by watching paramecia under a microscope. Place some scum in the water where they are and note how they collect around it. Place a very small crystal of salt in the drop where they are and note how they act in reference to it. The entire class may work at this if there are enough microscopes.

118. Draw a diagram of a nerve cell and label all of the parts. How does the impulse enter the cell? What is its course? Where does it pass out of the cell?

119. Topic.—What is the nature of the nervous impulse? Is it electrical? Is it chemical? Does it take time to travel, or is it instantaneous?

120. Draw various types of antennæ of crustaceans and insects from specimens. A hand lens may be necessary to see the joints of insects' antennæ. See Figs. 115, 116, 117, 118, and 120, Atwood's Biology.

121. Draw a diagram of the human ear from some book or model. Label all of the parts carefully and be able to reproduce it, when asked, from memory.

122. Demonstration.—Consult a physics text and set up a pendulum to demonstrate the laws of amplitude, of length, of material of the bob. This may be written up in the notebook after it is given to the class.

123. Consult the physics text again and set up a sonometer to illustrate the four laws of strings. They are the law of length, of tension, of diameter, and of material of which the string is composed. Write this up also and state how sound is produced. If these experiments have been performed in the classes in general science, a review only should be given now.

124. Student's Demonstration.—Stand before the class and hold a reading glass before a cardboard screen so that it will **form an image** of the window, or some object out of doors. Consult a good physics text. What is an image? What ways are there of forming them? What is a virtual image? A real image? Which kind is formed on the retina of the eye? If the room can be partly darkened, an image of a burning candle may be made to fall on the screen.

125. Draw a diagram of the human eye in the notebook and label all of the parts. Be able to reproduce the drawing and the names of the parts, when called on to do so, from memory.

126. Draw a diagram of the brain of the frog from Ward's models of the brains of typical vertebrates (Ward's, Rochester, N. Y.). Label the parts carefully, and learn the names of the parts of the brain, and the cranial nerves. See Fig. 136 and the table on p. 160 of Atwood's Biology. See also Fig. 43 in this book.

127. Social Recitation.—It is usually valuable to devote one laboratory period to an interchange of ideas and experiences on

animal intelligence, as it has been observed by the members of the class. There may be evidences of superstition, incorrect observation, faulty memory, etc. on the part of some students.

128. Debate.—Resolved that the dog can and does reason. In this debate your most conflicting arguments will center around the proposition, "What is reason?"

16. STUDIES OF PROTOZOANS

References

General Zoology, Pearse, Henry Holt and Co.
General Zoology, Linville and Kelly, Ginn & Co.
Practical Zoology, Hegner, Macmillan Co.
Life of Inland Waters, Needham and Lloyd, Comstock Pub. Co.
The Protozoa of Iowa, Edmondson, Davenport Acad. of Sci.
Civic and Economic Biology, Atwood, Study 25.

129. The Ameba.—These animals may be raised in the laboratory. The committee in charge of cultures may go to a pond (Break the ice if it is winter.) and secure some water weeds, particularly those which are covered with a great deal of slime. Place them in some glass pans and let stand for some days, when amebas may be found on the sides of the glass and in the sediment at the bottom. It will do no harm if the culture gets scum on its surface. Make several cultures, each different in some details from the others. The amebas on the sides of the glass should be taken off by rubbing the finger along the glass and transferring the material which it collects to a microscope slide. If any are found, they should be studied at once as they may be gone in a day or two. Note how they move, feed, and avoid objects in their path. Can the nucleus be found? Can a vacuole be found? How are the pseudopodia put out and taken in?

Draw an ameba in several shapes as it goes along.

If amebas can not be obtained by the method described above they may be had alive from the various dealers, and should be used at once upon arrival. They may be had permanently mounted on microscope slides also.

130. Paramecia.—These animals will be found, along with many other protozoans, in the cultures described above for obtaining amebas. The **hay infusion culture** is the surest. Several

should be made, and a little water from a pond or from the ameba cultures should be added to inoculate it. The hay should be chopped fine, and placed in water about two weeks before the protozoans are to be studied. A scum of bacteria will rise to the surface. This is the food on which the paramecia lives.

Place some of the scum on a slide and note their movements. We have referred to the **avoiding reaction** before. Can their cilia be seen? Note whether they go backwards as much as forwards. How rigid is the shape of their bodies? Can the nucleus be found? The oral groove? A vacuole? Watch one gather food. If they go too fast to be seen well, they may be entangled in some fibers of cotton if it is placed on the slide, or as the water dries they will become less active. A thin solution of gelatin will be of value also. Run it under the cover glass. As the protozoans swim into it, their motion is impeded.

131. **Other protozoans** will be found in the cultures with the amebas and the paramecia. Observe them, try to learn their names, and make some sketches of some of them. You will find various worms and crustaceans also. For the identification of the forms which you find see *The Protozoa of Iowa*, Edmondson, Davenport Academy of Sciences; and *Life of Inland Waters*, Needham and Lloyd, Comstock Pub. Co. The identification and enumeration of those found will make an interesting project for an individual or group.

132. **Questions.**—What is a **balanced aquarium?** Is a hay infusion balanced in this sense? Why does the culture die out? How long are the protozoans abundant in the culture? Would they become numerous again if more hay were added? How does a hay infusion differ from a balanced aquarium?

133. **Division.**—When the culture is at its best, you should be able to find specimens which are dividing. Look for them. They will seem to be double individuals. Are they just as active as the ones which are not dividing? Only a few people have seen the ameba divide, but hundreds of paramecia may be seen dividing in a good culture. They are about one half as large as others and are **attached end to end.** How long does it require to complete the process of division? See Figs. 144, 145, Atwood's Biology.

134. Conjugation.—In the same culture where the specimens are growing rapidly you should be able to find a few individuals which are conjugating. These specimens are **attached by their sides** and can be distinguished easily from those which are dividing.

135. Draw diagrams of specimens which are dividing and also ones which are conjugating. A good description of the conjugation of paramecia may be found in Hegner's College Zoology.

136. Notebook Work.—Write a description of the most successful methods of making a culture for paramecia. How many days after preparing the culture did the paramecia appear? How long do they stay? How many days is the culture covered with scum? On what do the paramecia feed? Describe the process of locomotion. Describe any other interesting things which were seen in the cultures. Consult references and describe division and conjugation.

137. Plasmodium malaria is the cause of chills and fevers. See Atwood's Biology, p. 176 and various other texts and write a description of its life history. Accompany your description with diagrams.

17. LESSONS WITH ALGÆ, MOSSES, AND FERNS

References

Practical Botany, Bergen and Caldwell, Ginn & Co.
Fundamentals of Botany, Gager, P. Blakiston's Son & Co.
General Botany, Densmore, Ginn & Co.
Civic and Economic Biology, Atwood, Studies 26, 27, and 28.

138. Gleocapsa is one of the simplest of the blue-green algæ. It may be found in greenhouses, in moist places, and in cultures of algæ which are kept in the laboratory, or it may be had from dealers. Place some cells under the microscope. Note the gelatinous envelopes which surround each cell, and how they may be within each other if the specimens are multiplying fast. As they grow, the older walls become dissolved away. Draw a single cell. Do you see a nucleus? Should there be one? Draw a group of cells.

139. Pleurococcus may be found on the north side of tree trunks, fence posts, and the like. It is very abundant and is one of the simplest of the green algæ. It has a nucleus and a chloroplast in which the chlorophyll is held. Is there a gelatinous envelope around

the cells as in gleocapsa? Draw a single cell and label the parts. Draw a group to show division.

140. Spirogyra is an advanced type of the green algæ. Illustrations of it are printed in nearly all of the books on biology and botany. See Atwood, Fig. 149 and 184. If some material was collected in the fall and preserved in formalin, it will probably show the stages of conjugation. Examine the cells of the filaments under the microscope. Note the shape of the cells and the filaments. Find the bands of chlorophyll which wind in spirals through the cells. Find the pyrenoids as dense areas along the bands. Run a drop of iodine solution over the preparation on the microscope slide, and after a few moments, the nucleus will be visible. The number of bands of chlorophyll varies in different species of spirogyra. How many bands has your specimen? See some of the illustrations in texts, make drawings of the stages of conjugation in spirogyra, and write a description of the process.

141. If time permits and material is available, **ulothrix** and **vaucheria** may be studied. Directions for their examination will be found in *Laboratory and Field Manual of Botany*, Bergen and Davis; and *A Laboratory Guide for General Botany*, Gager.

142. Make a table listing the advantages which **pleurococcus** has over **gleocapsa.** Show the advantages which **spirogyra** has over pleurococcus. What advantages has **vaucheria** over spirogyra. Understand from this table that there is an ascending complexity in the algæ. Copy one of the best tables on the board and discuss it in class.

143. Moss Plants.—It will be difficult to make a set of directions for the study of the moss which will be suited to many schools. The following are only suggestions.

144. Class Work.—Pictures of mosses may be passed around the class. Material showing sexes, and sporophytes may also be observed. Discussions of the various habitats of mosses may be valuable. Slides showing the protonema, antheridia, and archegonia may be thrown on the screen with a lantern.

145. Notebook Work.—A diagram of the life history of mosses may be put in the notebook. Write a description of it. These may be corrected by the archives committee and the instructor.

146. The fern may be studied as the moss above. It has roots, stems, and leaves. These may be studied, by making drawings of them or their parts. The spores, spore cases, antheridia, and archegonia must be seen under the microscope because of their small size. Permanent slides may be had from the dealers.

147. Notebook Work.—Write up the life history of the fern from the material which you have in the laboratory and the information which you get from Study 28, Atwood's Biology. If a more complete and detailed study of the fern is to be made, see Gager's laboratory manual, and Bergen and Davis also. Parts of these directions may be copied on the board.

148. Project.—Try to raise some mosses and ferns from their spores in the laboratory. Place the spores on moist soil in glass pans and keep them covered with glass plates or bell jars so they will not get dry. They must have a moderate amount of bright light. Have patience for they grow slowly.

149. Make a table listing the advantages of the **moss** over the **algæ.** Make another, or add to the same one, and show the advantages of the **fern** over the moss. Compare the tables in discussion in the class and write the best list on the board.

18. THE LIFE HISTORY OF THE PINE TREE

References

Civic and Economic Biology, Atwood, Study 29.
The botanies listed for the previous study.
Principles of Botany, Bergen and Davis, manual and text, Ginn & Co.
Text-Book of Botany, Coulter, American Book Co.

150. Field Trip.—If there are any pine trees near the school, they should be studied on a field trip. Compare the trees with others in size. How are their branches arranged? Are the leaves green the year around? How many seasons do the needles stay on? How are the needles arranged in their clusters? Are terminal buds formed at the end of each season's growth? About how much does the tree grow each year?

Do you find any resin on the bark? Do pines have sap or resin in their growing tissues? Can you find any cones? Are they all alike? How long does a cone stay on the tree. Bring some of the cones to the laboratory. Shake some of the seeds out (?).

151. Study Sections of Pine Wood.—How are their rings formed? Use a lens and see if there are any sap ducts? Can you find the resin ducts. Is pine lumber hard or soft wood? What is it used for?

152. Laboratory Study.—See as many of the parts of the cones of pines as you can (p. 196, Atwood's Biology; also Chap. XXVI, Gager's *Fundamentals of Botany*) and make drawings of some.

153. Notebook Work.—Write up the life history of the pine. See the two references mentioned above and also Bergen and Davis, *Principles of Botany*. This is a difficult study. Give it your most careful attention, and much time.

154. Museum Committee Project.—Make a collection of the various kinds of **conifer leaves.** Mount them on sheets on botanical mounting paper and label properly. Show them to the class and save for future classes.

19. THE PARTS AND FUNCTIONS OF THE FLOWER

References

Civic and Economic Biology, Atwood, Studies 30 and 31.
Botany of Plant Crops, Robbins, P. Blakiston's Son & Co.
General Science, Bowden, Chap. XXIII.

It is unfortunate that this study comes in the winter when flowers can not be had from the out-of-doors, but in these days of green houses and steam heat, they can be had at this season from indoor plants, and there are many things which urgent necessity compels us to study in the fall and spring; therefore this study has been put in the winter in Atwood's *Civic and Economic Biology*.

155. Secure flowers of various types from such sources as are in the school or the community and make a study of **petals, sepals, stamens,** and **pistils.** Note also **color, perfume, nectar,** and **arrangement.**

156. Draw a flower from a **monocotyledonous** and from a **dicotyledonous** plant. How do they compare as to the above mentioned features? It is not necessary that each student draw the same flower, and if time permits, several should be drawn. Fig. 169 in Atwood's Biology will be of assistance in labeling. See also similar figures in other texts.

157. Notebook Work.—Make a table of the various kinds of inflorescences and assign each flower in the laboratory to its proper place in the table. Make a list of the various ways which plants have of obtaining better **cross pollination,** and list an example opposite each method listed. Make a list of the most important **plant families** and name the chief characteristics of each. Name one or two plants in each family. These tables may be made out as a class project with the instructor as chairman. As the flowers are discussed samples should be passed around the class. When these are not available, pictures must suffice.

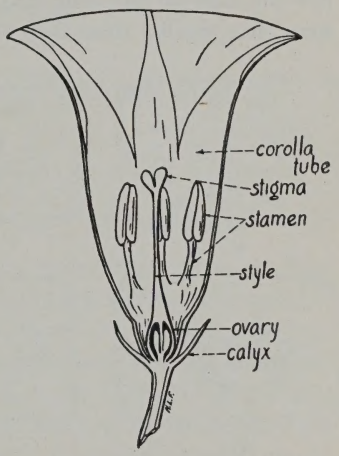


FIG. 29.—The sweet potato, to show the names and arrangement of the parts of a typical flower. (*Botany of Crop Plants, Robbins.*)

158. Germination of pollen is easily accomplished if the grains are placed in a solution of sugar of a strength of from 10 to 20 per cent. They should be viewed with a compound microscope. Will old pollen germinate? See Atwood's Biology, Figs. 166 and 187.

159. A flower calendar may be kept from year to year. When spring comes, let the students bring to the laboratory samples of the first flowers of each kind which are found and the dates of their first appearance may be recorded. Are the early flowers annuals or perennials.

160. A similar **calendar for the trees** to compare the times when their first leaves appear may be made also.

20. CELL DIVISION

References

Civic and Economic Biology, Atwood, Study 32.
Text-book of Zoology, Galloway, P. Blakiston's Son & Co.
Plant Anatomy, Stevens, P. Blakiston's Son & Co.
Being Well Born, Guyer, Bobbs-Merrill Co.

161. Cell Growth.—By using the microscope, examine cells of yeast, pleurococcus, spirogyra or some other single celled plant. Are the cells of the same size? Do you think that the larger cells were once smaller than they are now? Do cells grow?

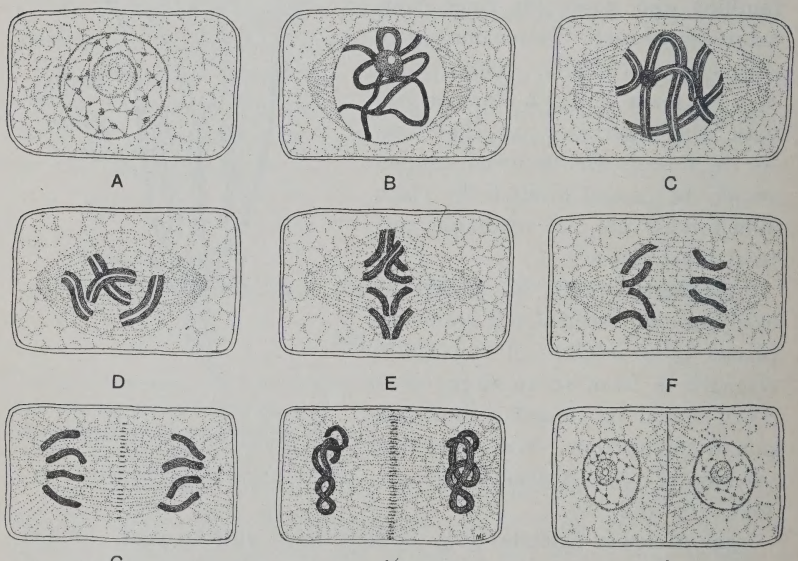


FIG. 30.—Diagram to show cell division (mitosis) in plant cells. (*Fundamentals of Botany, Gager.*)

162. Cell Division.—Examine the same cells as above and note those which have divided. Why has the spirogyra cell division resulted in the production of a filament and the division in pleurococcus a group of cells. Are all divisions in the same direction?

163. Cell Budding.—Examine yeast cells and note how they multiply by budding.

164. Draw types of the specimens which have been studied.

165. Chromosome changes in cell division may be shown by using permanent mounts of the root tips of the onion or some lily. These slides may be had from the dealers. Find cells which illustrate all of the stages of division shown in the illustration. The illustration in Atwood's Biology is of a typical animal cell. The one shown here is of a typical plant cell. Plant cells have no centrosomes. Write a description of cell division describing all of the changes which take place in the chromosomes.

21. THE LIFE HISTORY OF FLOWERING PLANTS

References

General Botany, Densmore, Ginn & Co.
Civic and Economic Biology, Atwood, Studies 32 and 33.

170. This study must be made from microscope slides or from lantern slides, unless the class and instructor are content to make it from illustrations in books. It is a difficult study for high school students, but it is valuable as completing the outline of the evolution of plants. It is interesting to know how the flowering plant came to be what it is. This study is also of value in understanding the subjects of heredity and plant breeding. If it were spring, it would be valuable to make a field trip and observe the great variety of flowering plants, and it should be understood that it includes grasses and trees which do not have conspicuous flowers. Understand also that the sporophyte and the grains of pollen are the only phases of the life history of flowering plants which can be observed naturally. All else must be especially prepared. Read Gager and Bergen and Davis for advanced references.

Directions for the study of the microscope slides which may be at hand will have to be written up by the instructor as it varies in different schools. Some students may assist by copying the directions on the board. See *Laboratory and Field Exercises*, Densmore.

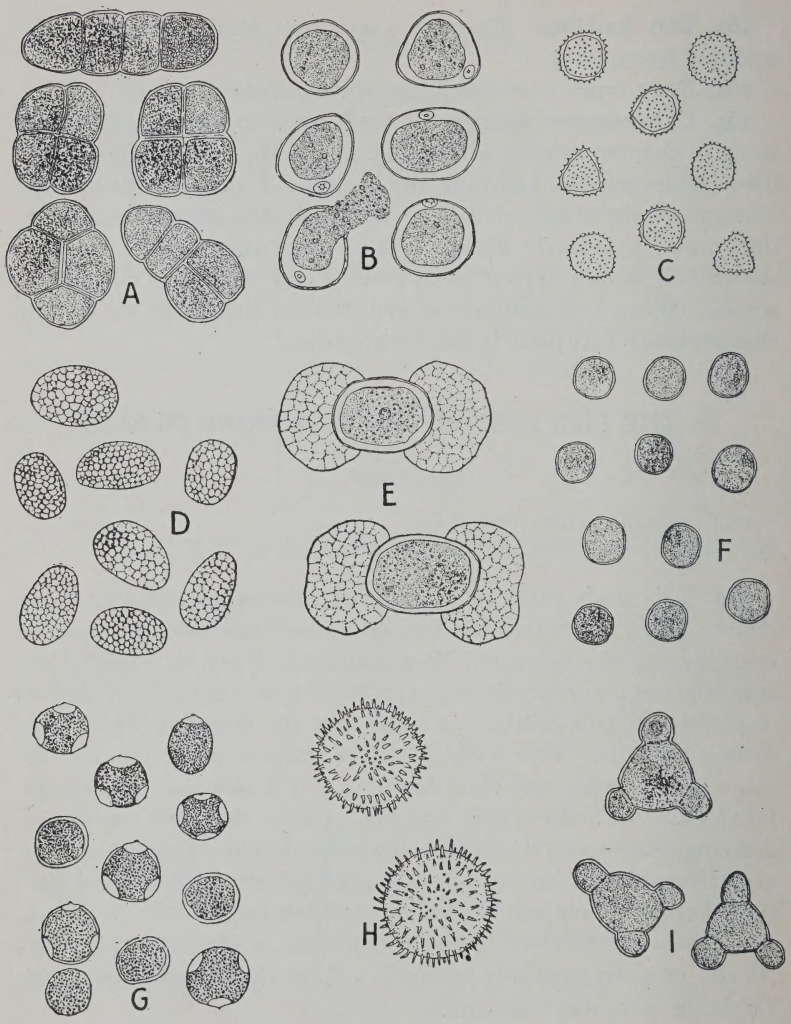


FIG. 31.—Types of pollen grains as seen under the microscope. *A, Typha latifolia; B,* corn; *C, Ambrosia elatior; D,* Philadelphia lily; *E,* pine; *F,* buttercup; *G,* blue beech; *H, Althaea rosea,* rose-mallow; *I,* primrose. (*Pharmaceutical Botany, Youngken.*)

171. **Pollen gains** may be viewed under the microscope. They are of a great variety of forms. See the illustration. If they were not germinated in sugar solution in a previous study, this may be done now. The pollen tube is a male gametophyte. Sketch some pollen grains and later, some which have germinated.

22. FRUITS AND SEED DISTRIBUTION

References

Botany for Colleges, Ganong, Macmillan & Co.
Practical Botany, Bergen and Caldwell, Ginn & Co.
Civic and Economic Biology, Atwood, Studies 34 and 35.
Interesting Neighbors, Jenkins, P. Blakiston's Son & Co.

Fortunately, most all fruits may be preserved easily in the museum either in the dried form or in formalin. The museum committee will get ready as many fruits and seeds as is convenient for the study. Write out the table, which appears in four columns on p. 233 of Atwood's Biology, in one column. Now write opposite its proper classification the name of each fruit which you have to study.

172. **Draw** various ones of the fruits which may be selected. Label their parts carefully and note on the drawing to which class they belong. Do not include any seeds in the drawings. They are to be studied later. Be able to state clearly the difference between fruits and seeds. Also, be careful not to classify any fruits as seeds.

173. **Make a table** of the methods of **distribution of fruits** in nature. Now go over the fruits which you have listed in the table of classification and list them according to their methods of distribution.

174. **Make a table** of the methods of **distribution of seeds** and fill it out as you did the one for the distribution of fruits. Seeds which are carried by the wind may be released in the room as a practical demonstration of how they are affected by a current of air.

After the study is made the museum committee will collect the fruits and seeds and save them for the next class.

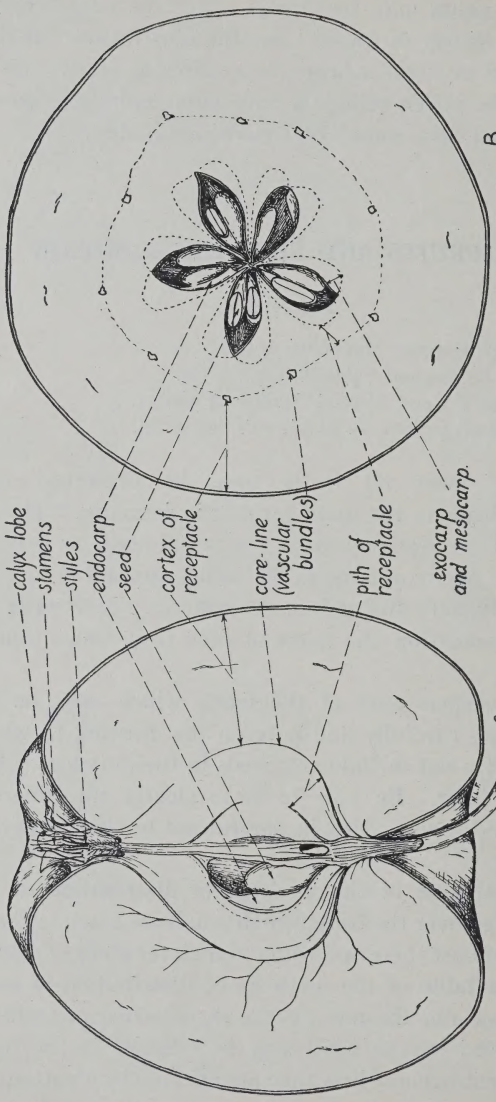


FIG. 32.—Sections of the apple to show the structure of a pome fruit. (*Botany of Crop Plants, Robbins.*)

175. Saturday Field Project.—A party of students may go for a tramp in the fields and woods. Make a collection of the seeds and fruits which are still on the weed stems, bushes, and trees. Make a collection of such seeds and burs as stick to your clothing. If there is a dog along with the party, his fur should be examined also. Bring the material before the class and discuss what you have learned.

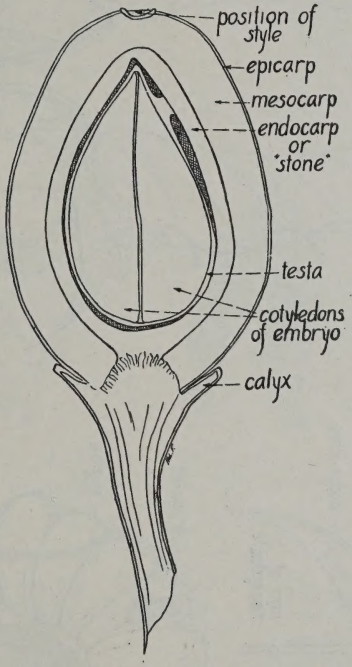


FIG. 33.—Section of a young cherry to show the structure of a drupe fruit. (*Botany of Crop Plants, Robbins.*)

176. Questions.—How many of the fruits and berries which were collected are eaten by birds? Would they be more apt to be eaten if they remained on the bush than if they fell on the ground? Why are unripe fruits green in color and sour or bitter in taste? Why are ripe fruits sweet and bright colored? Make a list of the ways which green fruits have of protecting themselves and give examples of

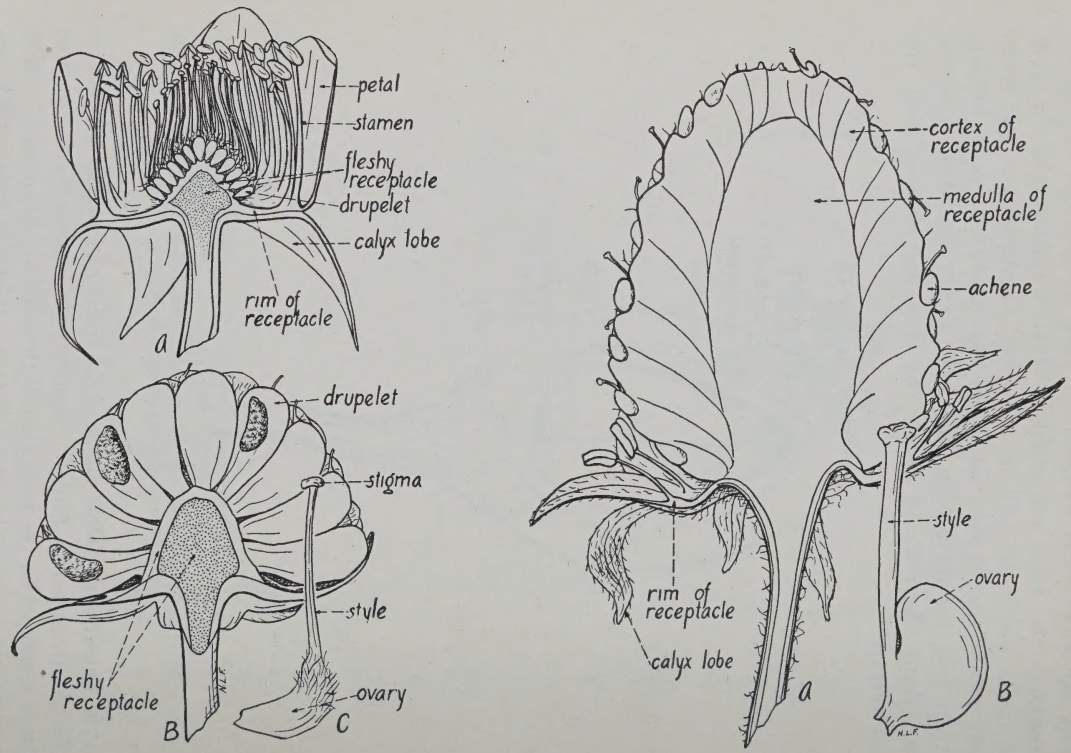


FIG. 34.—Section of the raspberry flower and fruit to show the parts of an aggregate fruit (left), and a section of the strawberry to show the parts of an accessory fruit (right). (*Botany of Crop Plants, Robbins.*)

each. How many kinds of apples do you know by sight? Make a list of those which you know. Do the same for other fruits. Do you

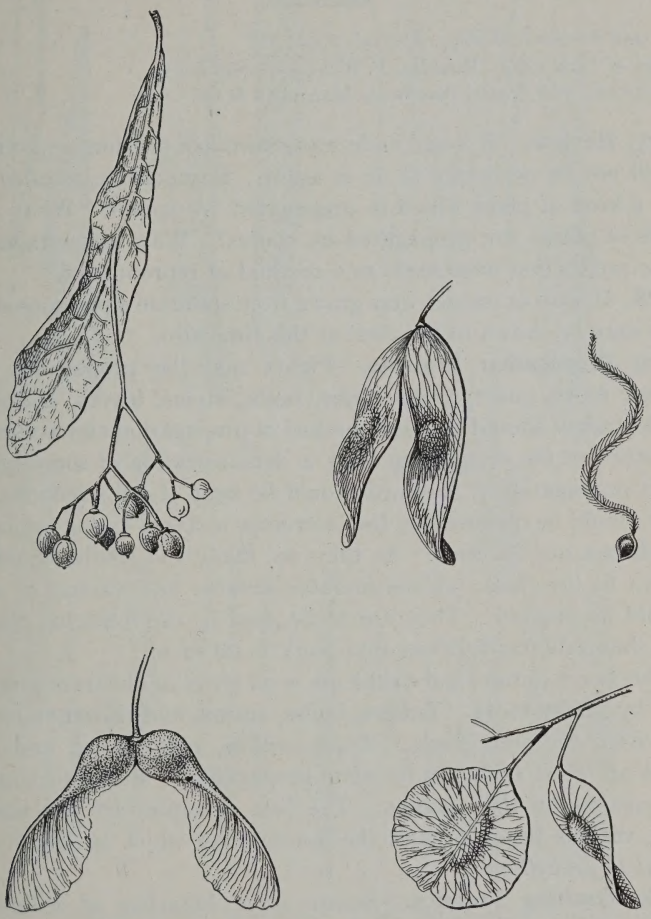


FIG. 35.—Winged seeds which are distributed by the wind. From left to right above—linden, ailanthus, and clematis; below—maple and elm. (*Interesting Neighbors, Jenkins.*)

know of any fruit which has no special method of facilitating its distribution?

23. STUDIES IN PLANT PROPAGATION

References

Civic and Economic Biology, Atwood, Study 36.
Botany of Plant Crops, Robbins, P. Blakiston's Son & Co.
Experiments with Plants, Osterhout, Macmillan & Co.

177. **Review.**—If bread mold was grown in a previous experiment, it will not be necessary to do it again. It should be recalled that it is a kind of plant which is propagated by spores. What other kinds of plants are propagated by spores? What advantages has spore production over seeds as a method of reproduction?

178. If ferns or mosses were grown from spores in a previous study, they may be shown to the class at this time also.

179. **Propagation Projects.**—Plants may be propagated from spores, roots, underground stems, bulbs, stems, leaves, and seeds. Each student should choose a method of propagation and attempt to prepare for the rest of the class a demonstration of some type of plant propagation. A record should be kept of the selections, and they should be reviewed by the instructor to avoid trying something which can not be done. As they are ready the results should be shown to the class. A considerable number and variety of seeds should be planted. They are to be used in the following studies, and should be ready when that work is taken up.

The sweet potato and dahlia are good roots to illustrate propagation by **fleshy roots. Tubers, bulbs, corms,** and **rhizomes** may be had from the seed stores. Apple, willow, cottonwood, and geranium are good examples for **stem propagation.** But few plants are propagated by their **leaves.** The best examples are the walking fern, various begonias, and the live-for-ever which belongs to the genus *Bryophyllum*.

180. **Grafting Practice.**—Secure some branches of willow, or other soft wood, grafting wax, raffia, and some sharp knives or scalpels. Let each student in the class make a graft after one of the methods shown in the illustration. Name the different kinds of grafts and learn for what use each is the best adapted. Why is grafting necessary in the fruit growing industry?

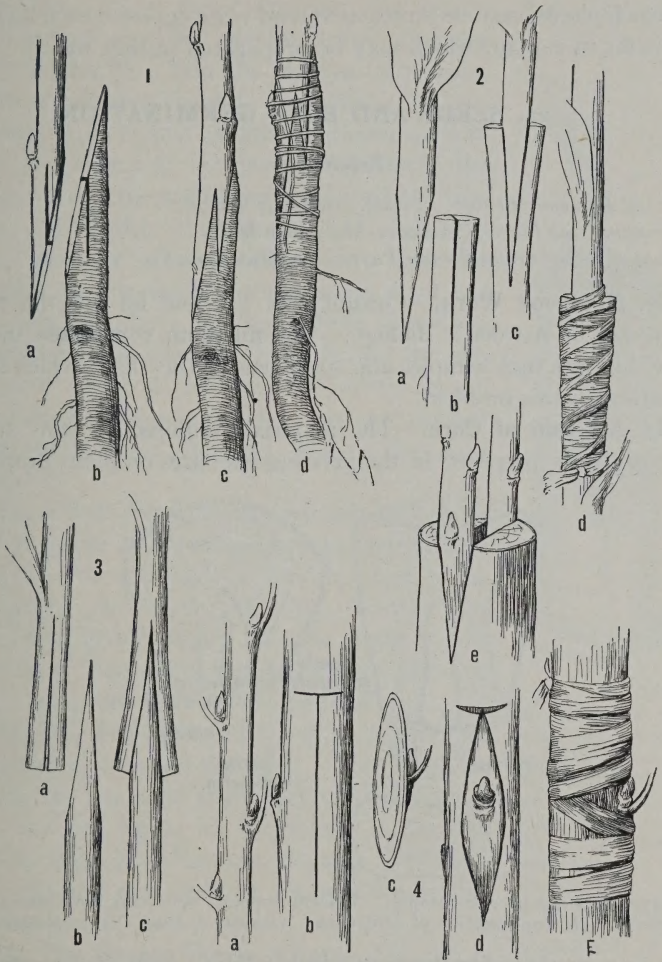


FIG. 36.—Various methods of grafting. From the Brooklyn Botanic Garden Leaflets. 1, Root grafting; 2, cleft grafting; 3, saddle grafting; 4, budding; *a*, scion; *b*, stock; *c*, the two united; *d* and *e*, the two tied with raffia. (*From Gager.*)

181. Notebook Work.—List in a table all of the different methods by which plants may be propagated, and write opposite each method the name of a plant which may be propagated in that way.

24. SEEDS AND SEED GERMINATION

References

Civic and Economic Biology, Atwood, Studies 37 and 38.
Experiments with Plants, Osterhout, Macmillan & Co.
Manual of Experimental Botany, Payne, American Book Co.

182. Notebook Work.—Consult Fig. 212 and fill out the table on p. 249 of Atwood's Biology. The **museum committee** should show the class such samples and specimens as they have which have a bearing on this problem.

183. A Grain of Corn.—The materials required for this study were probably prepared in the previous exercises on plant propaga-

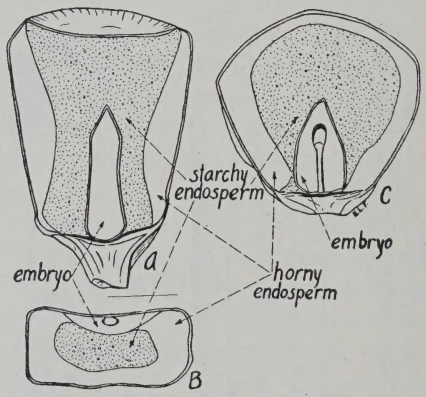


FIG. 37.—Sections of corn grains. *A*, Dent corn; *C*, flint corn, both lengthwise sections. *B*, Cross section of dent corn. (*Botany of Crop Plants, Robbins.*)

tion, as were those for the ones which follow. Soaked corn grains, and others in varying stages of development, should be observed. Consult Fig. 213 in Atwood's Biology; Fig. 22 in Payne's Botany; Chaps. VI and VII in Moon's Biology; pp. 56–59 in Hunter's Biology; and Chap. VIII in Gruenberg's Biology as references on this exercise and the ones which follow.

In the **corn seed** the endosperm has not been absorbed by the cotyledons. Test the endosperm for starch. Test the entire germinating seed for glucose. Test the dry seed for glucose. Test the embryo for protein. There is considerable oil in corn also.

Draw three or four germinating corn seeds to show the stages of the process. Identify the primary root, the secondary roots, and the root hairs. Note that the primary and secondary roots grow in opposite directions. Find the plumule sheath which surrounds the shoot but does not get above the soil. Note that there is but one blade when the plant breaks through the soil. This is followed by others in an alternating arrangement. Are they ever paired? What becomes of the corn seed as the plant grows?

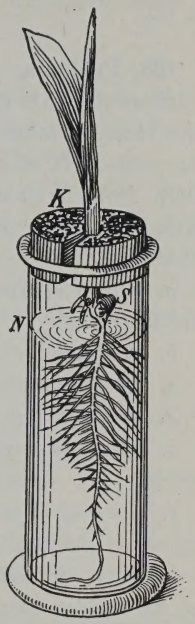


FIG. 38.—Method of making a water culture of a seedling to show the use of the endosperm or cotyledons. Make two cultures and remove the cotyledons or endosperm (*s*) from one of them. After some days compare the two cultures. (*Palladin's Plant Physiology, Livingston.*)

184. A Bean Seed.—The materials were probably prepared in the studies on plant propagation. Soaked seeds and some in varying stages of development should be available. Consult the references given above for the study of the corn seed, especially Atwood, P. 250 and Fig. 215. Study the bean seed as you did corn.

185. The Pea Seed.—Proceed as directed for the study of corn and the bean. The reason for adding the pea seed after studying the bean is that the pea leaves its cotyledons in the soil, and the bean lifts them into the air. Otherwise the bean and pea seedlings are very much alike in their germination.

186. The Squash Seed.—Consult Fig. 216 in Atwood's Biology and study squash seedlings as directed above for the others.

187. Topic.—Write a short paper setting forth the similarities and dissimilarities of the four seedlings which we have studied as directed above.

Additional and more complete directions for the study of seeds and seedlings may be found in Bergen and Davis, *Laboratory and Field Manual of Botany*, beginning on p. 17. Also Gager, *A Laboratory Guide for General Botany*, p. 16.

188. Projects.—The following projects should be chosen by various students who will work them out and present the solution to the class. Failures should be brought before the class as well as successes. It often happens that more can be learned from a failure than from a success. Do not bother the instructor for advice. Solve your own problem. Use all of the references which may be available.

a. Will seeds germinate without water, even if all other conditions are favorable?

b. Without air?

c. Without soil?

d. Without light?

e. At a low temperature? How low? Does it vary for different seeds?

f. Does soaking seeds before they are planted cause them to come up more quickly?

g. Must squash seeds be dried after they are taken out of the squash before they will grow?

h. Will seeds germinate in strong salt water? Why?

i. Fill a small flower pot with corn grains. Fasten the saucer on the top. Make it tight by binding it on with wire. Soak it in water, then take it out and keep it in a warm, moist place. Soak it in water once each day. Why must seeds exert force in germinating? What is the source of this energy?

j. Illustrate geotropism of seedlings.

k. Illustrate hydrotropism of roots of seedlings.

l. Illustrate phototropism with a seedling.

m. Plant some large and small seeds in the same dish. Which grow the faster? What is the advantage of the large amount of food in the larger seed?

n. Remove the cotyledons of various seedlings just as they sprout and compare them with others which have been left alone. Do seedlings get food from their cotyledons?

The reason for presenting the problems mentioned above as individual projects is that this method is more efficient as to effort, time, and space. It would not be possible for each student to solve each problem in an elementary course in biology.

189. Glucose may be tested for in various kinds of seeds which have germinated. Test the same seeds before they have started to germinate. Did you get so strong a test? Explain.

190. Problem.—At what depth do corn seeds germinate best? Plant grains of corn at various depths against the sides of a glass vessel, and when the ones which have germinated in the best order and way are ready show the vessel with its seedlings to the class. How deep should corn be planted? Should all seeds be planted at this depth? Why the difference?

25. LIFE HISTORIES OF ANIMALS

References

Civic and Economic Biology, Atwood, Studies 39, 40, and 41.
All of the zoologies and biologies deal with this subject.
Secure the embryological models of amphioxus, frog, and chick from the dealers in biological supplies.

191. The Fish.—Developing eggs of various species of fish may be had from the U. S. Bureau of Fisheries or some of the stations, and from dealers in biological supplies. For references see Kellogg and Doan's Zoology; and Civic Biology by Hodge and Dawson, Chap. XXVII.

192. Draw a series of developing eggs to show the progress from an egg to a fish.

193. The Frog.—If frogs' eggs were collected and preserved in formalin the previous spring, they may be studied under the microscope. Try to find two, four, and eight cell stages in the cleavage of the egg. Eggs in various stages of development may be had from the dealers in Biological supplies.

194. Draw the stages of cleavage of the frog's egg which you find.

195. The tadpole may be studied from material which was preserved from last spring's catch, purchased from dealers, or from charts. See Fig. 224 in Atwood's Biology. Before the frog's egg hatches the tadpole can be seen to move within the white of the egg. When it comes out, it has no mouth but clings to objects with its sucker. It is black and is covered with cilia. Find a stage with external gills. As these are withdrawn, the internal ones appear. Which legs appear first? How is the tail disposed of? What does the young tadpole eat? When does it first begin to breathe? When are frog's and toad's eggs laid? When do they develop into frogs and leave the water?

196. Draw a series of tadpoles to show the progress from an embryo to the fully formed frog from actual specimens or from models.

197. The Bird.—Excellent wax models of the stages of development of the chicken's egg may be had from the dealers. Eggs may be incubated in an incubator and the living embryos may be seen. Chicken, pigeon, and turtle embryos which have been mounted permanently on microscope slides may also be purchased. Consult the illustrations in Study 40 of Atwood's Biology.

198. Draw a series of chick embryos to show development from the egg to hatching. Label as completely as possible, but do not expect to know all about bird embryology in this brief study. If you get the general trend, it will be sufficient.

199. The Mammal.—It will be more profitable, in the majority of schools, to spend more time on the development of the chick and to leave out the study of mammalian embryos. Pig embryos are the most frequently studied. They may be had from the dealers, either entire or sectioned and mounted on microscope slides. It may be profitable to study, observe, or draw a series of wax models to show the development of the ear or another series to show the development of the eye. If this is done consult Figs. 122, 123, 132, 233, and 234 in Atwood's Biology.

26. THE FROG

References

Civic and Economic Biology, Atwood, Figs. 22, 91, 98, 122, 136, p. 162, and Study 39.
General Zoology, Linville and Kelley, Ginn & Co.
New Essentials of Biology, Hunter, pp. 272–281.
Biology for Beginners, Moon, Chap. XXVIII.
Comparative Vertebrate Dissection, Atwood, P. Blakiston's Son & Co.
Anatomy of the Frog, Ecker, Oxford.
Laboratory Directions in Zoology, Guyer, U. of Wis. Press.

200. **The living frog** should be examined first. They may be kept in the laboratory indefinitely by feeding them twice a week. The first exercise may be a demonstration of **how to feed a frog.** Place them in a dish with glass sides so the class may see what goes on. They should be left here long enough to become quiet, and then if pieces of meat are dangled before their noses on a wire, they will take the meat readily. Put the meat on the wire so that it may be pulled off easily. Will a frog eat meat that is not moving? Will they take food which is not good for them? Do they swallow all kinds of food? Are their abilities to taste well developed? Are they especially attracted by certain colors? What do they do when they secure a piece of food that is a little too large to handle easily?

Put one frog in the dark and one in the light. How are their shades of color effected? Note the spots and markings. Are they protective? Learn to know the kinds of frogs by their markings. Note that the skin is moist. It is used as a respiratory organ.

Locomotion.—How does the frog walk, jump, and swim? Compare the legs. How is each pair used? Compare their joints with those of man's. Locate the elbows, wrists, knees, and ankles. Note that the frog has no tail.

The head of the frog is possessed of a very large mouth, eyes, nostrils, and ears. Find these structures. Can the frog wink? Can it move its eyes? Compare the upper and lower lids. The **nictitating membrane** is a third eyelid which is transparent. Observe it.

Breathing is accomplished by filling the throat with air and then swallowing it into the lungs. Observe a frog as it breathes. How is the air expelled? Can it breathe with its mouth open? An alligator breathes much the same as a frog, but can do so with its mouth open. Can you explain? Hold the frog between the finger and thumb by placing them under its arm-pits. The frog usually croaks. Can it croak with its mouth closed? Of what value is the frog's ability to croak in nature? Can it croak under water?

Circulation of blood may be shown by placing a frog's foot under the microscope. Various ways of doing this have been devised. If you make this exhibit, do not injure the frog.

The dead frog may be placed in a pan of water and cut open on the ventral side to remove some of the formalin in which it has been preserved, or if it is fresh we may study the inside of the **mouth.** Consult the figure and locate the parts which are named. The **Eustachian tube** may be traced to the ear chamber by inserting a probe. The **lungs** of a fresh specimen may be inflated by inserting a blow-pipe in the trachea.

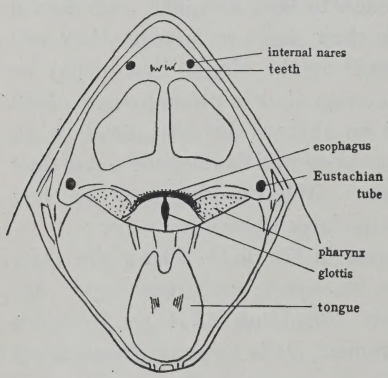


FIG. 39.—The open mouth of the frog to show the structures within. (*Drawn for this work by J. Thranow.*)

The skin is loose and may be removed easily. Note the blood vessels which enter the skin near the fore legs. What is their use?

The body-cavity may be explored after a cut is made along its mid-line from the throat to the hip girdle. Find the **heart.** If the specimen is freshly killed it will be beating. The **liver** is the large dark red organ in the middle of the cavity. On the frog's left and under the liver is the **stomach.** Trace the **intestine** from the stomach to the pelvic region. Note its coils. Near its posterior end it is enlarged to form a **rectum.** At its terminus is a large sac which is the **urinary bladder.**

The egg masses may have interfered with the observation of the intestine if the specimen was a female. The eggs are held in a large

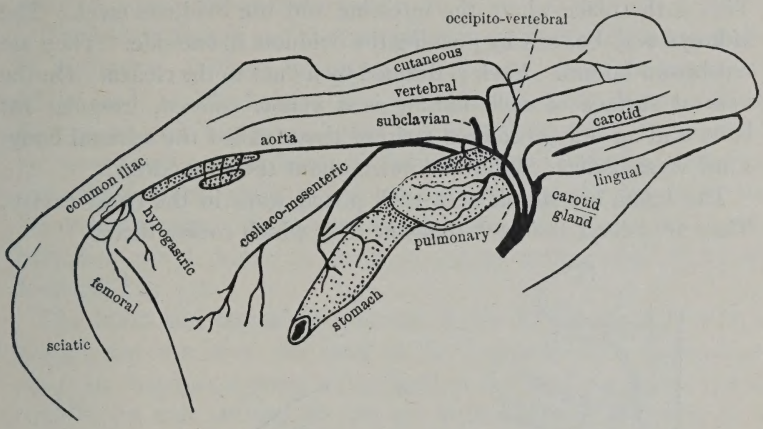


FIG. 40.—The arteries of the frog.

sac of the ovary until spring when they are laid. How large are they? What is their color? Remove the eggs and find the large,

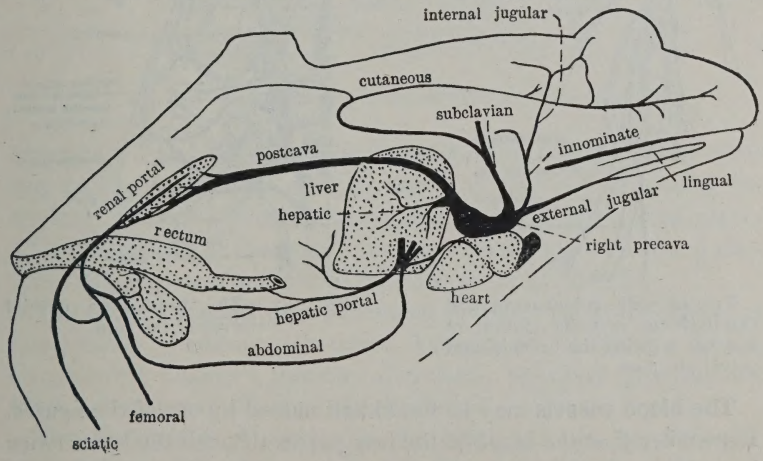


FIG. 41.—The veins of the frog.

coiled, white tubes which are the **oviducts.** Their walls contain stored nutriment which is added to the eggs as they are laid. Each

egg is passed from the ovary into the cavity of the body, from where it enters the open end of the oviduct to be passed to the **cloaca.** This is the place where the intestine and the oviducts meet. The **kidneys** may be seen by pushing the oviducts to one side. They are red-brown bodies. Each is drained by a duct to the cloaca. On the ventral surface of each kidney is a yellow colored, irregular **fat body** and an orange colored strip of tissue called the **adrenal body.** Find these bodies. What is known about their functions?

The lungs are simple sacs with pitted walls in the chest cavity. They are nearer the back than the liver which covers them.

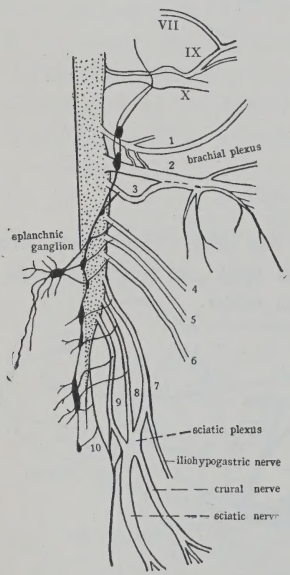


FIG. 42.—The spinal nerves and sympathetic nervous system of the frog showing the brachial and pelvic plexuses.

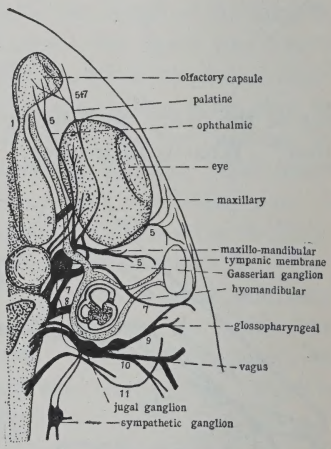


FIG. 43.—The brain and cranial nerves of the frog.

The blood vessels may be found and named by use of the figures. Remember that the blood of the frog passes through the heart twice in making a complete circuit of the body. (See Figs. 98 and 99 in Atwood's Biology.) If the specimens are injected, or are fresh, this will not be difficult. But it is not possible in high school classes if the specimens have been preserved without injection.

Mesenteries are thin sheets of tissue which hold the organs of the body-cavity in place. Find them and name them after the organ which is suspended in each case.

The spinal nerves and the **sympathetic nervous system** are shown in the figure. Look in the cavity of the body, along the inner wall of the back, and find the white cords which are the nerves. Compare them with the figure. Can you find them all? Those which are associated at the level of the arm form the **brachial plexus,** and those which unite to send branches into the leg form the the **sacral plexus.** Each nerve trunk leaves the spinal cord by two branches which unite to form a spinal nerve. See Atwood's Biology, Fig. 138.

The brain and **cranial nerves** are shown in the figure. With a sharp pointed scissors the skull of the frog may be cut open from above by inserting a point in the back of the skull where the spinal cord leaves and cutting bit by bit until the roof of the skull is

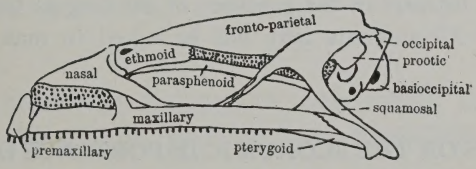


FIG. 44.—Side view of the skull of the bullfrog.

removed. The brain should be seen and its parts identified by referring to Fig. 136 in Atwood's Biology. It may not be possible for students of high school grade to identify all of the cranial nerves which are shown in the figure, but they should be found where they arise near the brain and traced outward as far as possible.

The muscle system may be studied by referring to the figures in *Comparative Vertebrate Dissection*, Atwood, P. Blakiston's Son & Co.; *General Zoology Laboratory Directions*, Sigerfoos, Minneapolis, Minn.; *Anatomy of the Frog*, Ecker, Oxford.

The skeleton is divided into the **axial** and the **appendicular** parts. The axial consists of the **skull** and **vertebral column.** A view of the skull is shown here. If skeletons are available, the bones of the skull may be identified. The bones of the vertebral

column are the **vertebræ.** Each consists of a **centrum** which is the main part of the bone and a **neural arch** which surrounds the nerve cord. At the sides are the **transverse processes** which terminate in **short ribs.** It may almost be said that frogs have no ribs. The last bone in the vertebral column is the **urostyle.** Account for its peculiar shape.

The appendicular skeleton consists of the **limbs** and their **supporting bones.** The **shoulder girdle** is a curved plate of bones and cartilage which supports the front legs. It is not closely attached to the axial skeleton. The **humerus** is the first bone of the front leg. The **radius and ulna** are united to form the bone of the forearm. How many wrist, hand, and finger bones are there? The **pelvic girdle** supports the hind legs. Is it attached to the vertebral column? The first bone in the leg is the **femur.** The **tibia** and **fibula** are united in the shank of the leg. The ankle is long and contains two long **tarsal bones.** How many toes are there?

Draw such features of the anatomy of the frog as the instructor may direct. All students may not be asked to make the same drawings.

27. STUDIES ON THE ECONOMIC IMPORTANCE OF DOMESTICATED ANIMALS AND PLANTS

For a reference see Unit V, Atwood's Biology.

The author has not been accustomed to do any laboratory work with this section of the work. It has been interesting to work up topics and reports, and devote a few minutes each day to the giving of them to the class; but their nature must depend upon the references which are available, their number, and upon the time which is given to this unit of the book.

201. Library Committee Work.—Prepare lists of reports on the subject matter of the first half of Unit V of Atwood's Biology which, in your judgment, can be made up from the reference material available in your library. Submit them to the instructor for approval and let the members of the class select such as they wish to work on. This should be done before this study is taken up in class.

202. Exhibits.—The **museum committee** should prepare exhibits of such grains, fruits, vegetables, etc. as are available and as will be instructive to the class.

203. Government bulletins of the department of agriculture may be had for the asking. Write to the Editor in Chief of the Department of Publications, Department of Agriculture, Washington, D. C., and get your name on the monthly mailing list of announcements of new bulletins. Much valuable information bearing on these studies may be had from these bulletins. They should be placed in charge of the library committee. It is possible to get a catalogue of bulletins which have been published in the past and are still in print.

204. Class Projects.—Make a tabulation of the **domesticated plants** and list their wild ancestor, or ancestors, and the country from which they came.

Repeat the above for the **domestic animals.** If time is short, a select list may be sufficient in both cases.

28. VARIATION AND HEREDITY AND THEIR APPLICATION TO PLANT AND ANIMAL BREEDING

References

Civic and Economic Biology, Atwood, Studies 46 and 47.
Heredity and Evolution in Plants, Gager, Chaps. IV and V.
Being Well Born, Guyer, Bobbs-Merrill Co.
Genetics, Walter, Macmillan Co.
Elementary Biology, Gruenberg, Part V.

205. Variation Study.—Refer to Fig. 256, Atwood's Biology and make a list of all of the ways in which the two ears of corn differ, the one from the other. When the lists are complete they should be compared in class. Note length, diameter, kernels in the row, size of kernels, rows of kernels, butts, tips, shape of ear, curved or straight, and any other variations which you may note. What might have been the cause of some of these variations?

206. Reports may be prepared on cases of **discontinuous variations** which are known in the literature of science.

207. Tabulate all of the animals which you know to produce **albino** offspring on occasions. List the dates and places of occurrence. Make another table for the occurrence of **black** animals.

208. Exhibits.—Try to secure for exhibition purposes in the laboratory specimens of Andalusian fowls, white rats and mice, guinea pigs, and hybrid plants.

209. Chromosome Chart.—See p. 314 in Atwood's Biology and by referring to the chromosome inheritance chart write an explanation of how the laws of Mendel and the theory that the chromosome is the carrier of the determiners of heredity are in agreement.

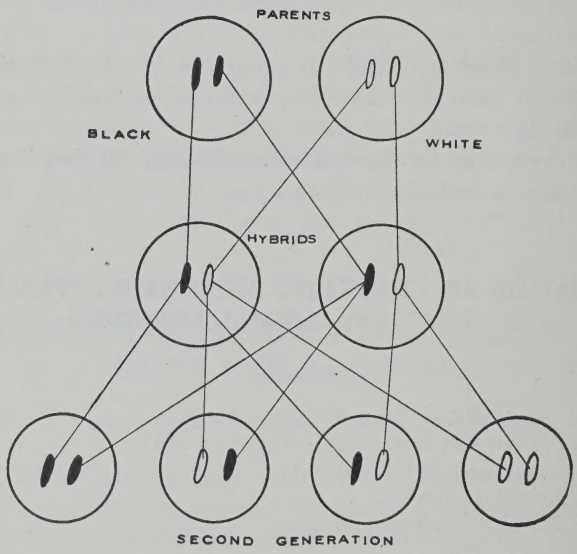


FIG. 45.—Chart to show how the chromosome theory of inheritance is in accord with Mendel's laws. The chromosomes which carry the determiners of black color are black in the figure, and those which carry white are white.

210. Exhibit.—If possible specimens of various breeds of corn, wheat, apples, squashes, etc. should be shown to the class.

211. Quetelet's Law.—This is the **law of chance.** It may be illustrated by taking ten pennies and throwing them up a thousand times and recording the number of heads and tails in a table with eleven columns; or five pennies may be chosen and recorded in a

table with six columns. In this case it may be sufficient to throw them up about 500 times. Take your results to an adding machine and compare. Plot a curve of the results. **Continuous variations** follow this curve in their occurrence.

This law may also be shown with the apparatus which is illustrated in Fig. 394, *Fundamentals of Botany*, Gager.

Secure 100 earthworms and count the rings in their bodies. Collect the data in a chart and plot the curve. Is it a Quetelet curve?

Secure 100 ears of corn of the same variety and count the rows of kernels, or measure the lengths, or diameters. Suggest other problems or projects which might be worked out. Do you fully realize the universality of this law?

212. Board Work.—Write down the various types of **discontinuous variations** in a table form. Recall or give examples of the various cases of mutations of which you know or have read. Assign each to its proper place in the table. When this is done, the table may be copied in the notebook.

213. Trap Nests.—A report may be given to the class on the subject of increasing the production of eggs by trap-nesting the laying hens.

214. The Babcock Milk Test.—A demonstration of this test may be given here if it was not done in connection with the food tests. Of what value is milk testing in improving cows?

215. Corn testing and **judging** demonstrations may be carried out before the class. See Government Bulletins for directions.

216. A report may be given to the class on the life and work of **Luther Burbank.**

217. Prepare a list of the wild animals in your community which are hunted and trapped for their furs. Which ones will live and breed in captivity? What are the game laws which protect them? If our wild life continues to decrease as it now is, we will soon produce nearly all of our furs from domesticated, furred animals. If there is a fox, skunk, or muskrat farm in the vicinity it may be possible to make a study of it.

218. Animal Improvement Study.—Refer to Figs. 250 and 251 in Atwood's Biology and make a list of the changes which have taken place in the production of the zebu cattle from the wild banteng.

29. EUGENICS AND EUTHENICS

References

Civic and Economic Biology, Atwood, Studies 46, 47, 51, and 52.
Civic Biology, Hunter, Chaps. XVII and XXIV.
Civic Biology, Hodge and Dawson, Chap. XXX.
Genetics, Walter, Macmillan Co.
Being Well Born, Guyer, Bobbs-Merrill Co.
The Next Generation, Jewett, Ginn & Co.

219. Reports on state laws on eugenics, marriage laws, population of the asylums of the state, tree ordinances, nature of adenoids, duties of the health department, results of school inspection for teeth, eyes, and other ailments needing attention, suggestions for improvement of the ventilation, lighting, and heating systems of schools, relative humidity, child labor laws in your state, value of pure water and milk, etc., are of great value. We can not hope to make much more progress in civic betterment along biological

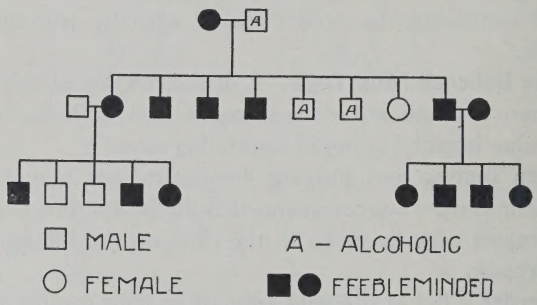


FIG. 46.—Three marriages to show how feeblemindedness is inherited. Describe in writing what the results are as shown in the diagram. (*General Science, Brownell.*)

lines until the general public has more information of these matters than it now has, and until it has a greater desire to profit by such knowledge.

220. Table of Inherited Defects.—Make a tabulation on the board of the defects which people have which are inherited. If there is doubt about it, write a question mark to so indicate. Copy the table in the notebook and file a copy with the archives committee.

221. Research.—Consult the table on p. 306, Atwood's Biology and understand how inherited defects are charted. If you know of any people or animals having **inherited defects,** try to get some data concerning them and their relatives. When it is collected it should be charted as in the figure. In making such surveys be very careful to avoid giving offense to people who may be sensitive.

222. Family Survey.—Make an **inheritance chart** of the occurrence of Mendelian characters in your family. Make the chart as inclusive of as many individuals as possible. Eye-color, hair-color, curly or straight hair, fatness, and musical ability are such characters as may be easily charted.

223. Questions.—Is feeble-mindedness dominant or recessive? Can normal children be born from feeble-minded parents? If feeble-mindedness is due to disease or injury, will it be inherited? Is insanity inherited? May it be caused by injury? If there are 110 millions of people in the United States and 20 per cent of them have some inherited defect, how many such people have we? Make a list of human defects and classify them as to whether they are bad enough to be eliminated by segregating those who have, them or should no restrictions be placed upon them. Baldheadedness and fatness are of the kind which should not be restricted. Should one consider the relatives of the person whom one wishes to marry? Is a person to be blamed for being a defective? Therefore, should we not be charitable to them?

224. Shrub Study.—Make a trip through the city to study the shrubs which are used for improving the appearance of yards and boulevards. Make a list of them, and star the best ones. See the catalogues of nurserymen as references.

225. Landscape Garden Plans.—Have the local landscape gardner give the class a talk on the science and art of his profession. Make a diagram of your home and the shrubs and trees which surround it. Is there room for improvement? Will there be some flower beds next summer? Have some of the plans put on the board and discussed as to possible improvement by the class.

226. Notebook Work.—Answer the questions which are asked in the studies on eugenics and euthenics in Atwood's Biology, Studies 51 and 52. Read the following references and write an outline or

summary of each: *The Kallikak Family* by Goddard, the *Zeros* by Poellman, *Noteworthy Families* by Galton, *The Heredity of Richard Roe* by Jordan, and the *Descendants of Jonathan Edwards* by Winship.

30. THE DOCTRINE OF EVOLUTION

References

Civic and Economic Biology, Atwood, Unit VI.
Heredity and Evolution in Plants, Gager, P. Blakiston's Son & Co.
The Theory of Evolution, Scott, Macmillan & Co.

227. Field Trips.—Go to a stone quarry, gravel bed, the shore of the ocean, or one of the Great Lakes and study the **fossils** which are to be found there.

Go to a museum and observe the fossils which are there.

Various members of the class may be able to bring fossils to the class for observation.

228. Reports may be given on the ancestry of the horse, elephant, camel, birds, mammals, ancient and primitive man, plants of the carboniferous period.

229. Demonstration.—Compare the skeletons of various animals to demonstrate that all vertebrates are built on the same plan. What other systems may be used to show this?

230. Table of Vestiges.—Make a tabulation of the various vestigial structures of animals which you know and list their probable use in ancestors which had them in a perfect form.

231. Reports on the lives of some of the great men of biology may be prepared and given from time to time as they are ready.

232. Overproduction Computations.—If we start with a pair of flies in the spring, and the female lays 200 eggs, and the young develop and lay eggs again in 30 days, and the summer lasts five months, how many flies will there be at the end of summer?

If a certain weed produces 3,000 seeds in a season, and all grow each year, how many weeds will there be in ten years? If each weed weighs ten pounds, how much will all of them weigh?

If a pair of eagles produce two young each year and live to be 100 years old, and if breeding takes place the second year, how

many eagles will there be at the end of 100 years? If this problem is too long, it may be estimated.

233. **Struggle for Existence Experiment.**—Plant several kinds of seeds in a box or tray. Plant a great many seeds. Give the culture the best of care. What seedlings survive? Did they struggle? Is it not obvious that they can not all live?

234. **Reports.**—List the different kinds of the following animals and plants which man has produced by natural selection. Do not be discouraged if you can not give a complete list. Get as many pictures to show as you can.

Varieties of dogs.
Varieties of chickens.
Varieties of doves.
Varieties of apples.

Reports of famous biological experiments and discoveries will be interesting and valuable.

31. BACTERIA, YEASTS, AND MOLDS

References

Civic and Economic Biology, Atwood, Studies 56 and 57.
Practical Botany, Bergen and Caldwell, Chap. XI.

235. **Bread mold** may be grown on bread by moistening it and placing it in a warm, damp place for a day or two when it will be covered with the hyphæ of the fungus; and in a day or two more, the black spore cases will appear.

Growth tests for bread mold may be made as follows: Secure eight wide mouthed bottles or tumblers. Place a piece of bread which is wet in each vessel and treat each as follows:

1. Do nothing. This is the **control.**
2. Remove the bread from the glass. Clean the glass and dry it. **Dry** the bread completely and replace it in the glass.
3. Cover the piece of bread with dry **salt.**
4. Cover the bread with vinegar or some other **acid** as boracic.
5. Place enough **sugar** on the bread to cover it. Corn sirup may be substituted for the sugar.

6. Place the glass containing the moistened bread in **boiling** water in a double cooker or a sterilizer. Keep covered after removing.

7. Place this one in a **refrigerator.**

8. Place on the bread a dilute solution of **formalin.**

Place all but No. 7 in a warm place and keep each vessel covered to prevent evaporation and more infection. In order to make sure that each was infected with mold, it might be well to inoculate each piece at the start. The cultures should be examined at the end of four days and the results written in the notebook. Be sure to explain why mold failed to develop in the sterile cultures.

236. Microscopic Work.—**Bacteria** may be spread on microscope slides, dried, stained, and viewed with the high power.

Yeasts are easily seen. They are very large cells. Place a drop of the culture in which they are growing on a microscope slide and view under the low and high power. What is the shape of the cells? Note how they grow by budding. Can you find a nucleus? A drop of iodine on the slide will enable you to avoid starch grains. How?

Draw some yeast cells to show their shape, nuclei, and their method of growth and reproduction.

237. Project.—Refer to Atwood's Biology, Fig. 299 and make some **wax models** of various kinds of bacteria as suggested.

238. Molds.—From some of the cultures of bread mold which you have grown, you may secure material which can be viewed under the microscope. Find the **hyphæ, stolons, rhizoids, sporangiophores,** and **spore cases** (sporangia). **Make a drawing** showing these structures and label carefully.

239. Culture Medium.—The best medium for the cultivation of bacteria is the beef extract-agar-bouillon. To make it, dissolve ten grams of each of the following materials in 200 cc. of water: Leibig's beef extract, salt (NaCl), and peptone. In 800 cc. of boiling water dissolve ten grams of agar-agar (or 100 grams of gelatin). The agar must be given considerable time in which to dissolve, and must be kept at a boiling temperature in a double cooker. Pour the first solution into the second and filter *while hot* through cotton. It should be clear. If it is not, it should be heated again and refiltered.

Pour the hot culture medium into sterilized test tubes and Petri dishes. The dishes should be covered immediately and the test tubes should be plugged with sterilized cotton. Set these away to be inoculated in the following experiments.

Note.—This solution should be made by the instructor or by a responsible committee. If the medium is to be used for bacteria, it should be made slightly alkaline by the addition of sodium carbonate; but if it is to be used for molds, it should be slightly acid. Determine the acidity or alkalinity after it is filtered by using litmus paper.

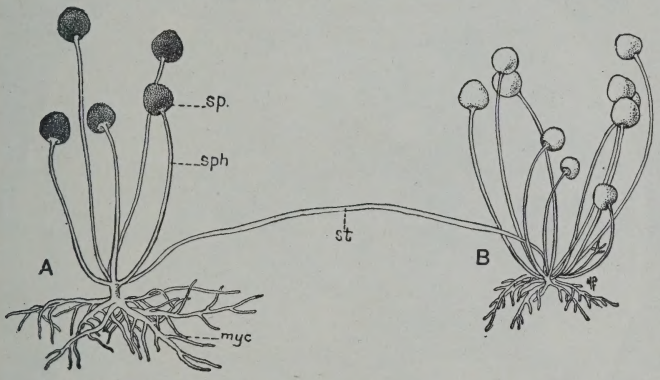


FIG. 47.—Bread mold (*Rhizopus nigricans*) to show its habit of growth. *A*, Older plant with ripe spores; *B*, younger plant with unripe spores; *myc*, mycelium; *sph*, sporangiophore; *sp*, sporangium; *st*, stolon. (*Fundamentals of Botany, Gager.*)

240. Where may bacteria be found?—Expose the Petri dishes in some of the following ways. To the dust of the room while it is being swept. To dirt from under the finger nails. To a comb after passing it through the hair. Wash the hands in a small amount of water and place a drop of it on the culture. Scrape the teeth with a dry, sterile tooth brush and inoculate a culture with the scrapings. Get some dust from the road, from a window ledge, from a basement, and other places and inoculate cultures.

Keep the cultures in a warm place and do not let them dry out. Watch them and report the growths as they take place. Do not remove the covers when examining Petri dishes. Compare the

growths in the different dishes. How can you tell molds from bacteria? Are there any differences in the kinds of molds and the kinds of bacteria? Do you fully understand how these fungi got into the Petri dishes? Are bacteria everywhere in the house and out of doors? Probably none of the bacteria which you have grown

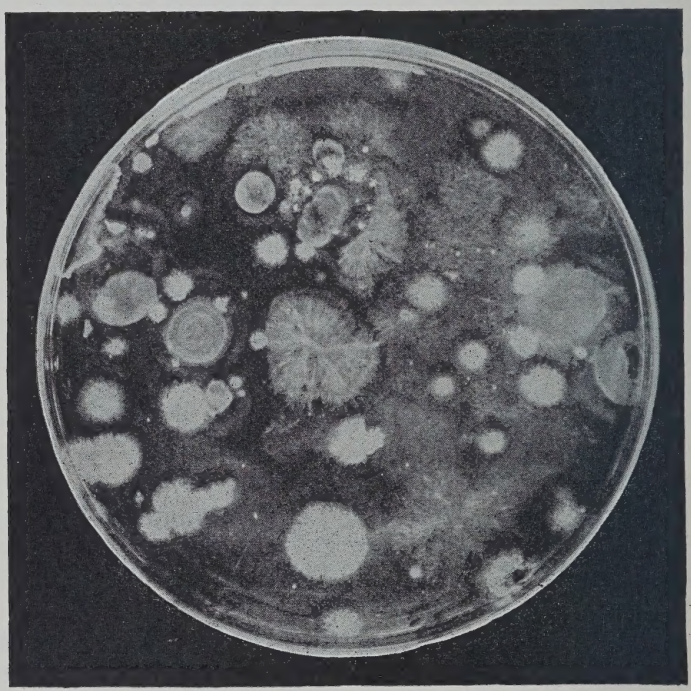


FIG. 48.—A plate culture of colonies of bacteria grown from a bit of dust from a cow stable. (*Microbiology, Marshall.*)

are dangerous to man as producers of contagious diseases, but if you had secured your inoculating material from a sewer, spittoon, or scab it would be dangerous.

241. Pure cultures of bacteria may be made by thrusting a sterilized needle or platinum wire in a spot of bacteria in a Petri dish and then thrusting it in the culture medium which you have saved in a test tube. Be very careful to avoid letting any foreign bacteria

get into the tube when the inoculation is made. After a few days the tubes may be examined. If you were careful, there will be but one kind of bacteria in a test tube. Do you fully appreciate how careful one must be to avoid bacteria which cause decay or disease?

242. Problem.—If the *bacillus tuberculosis* divides every half hour when it is growing rapidly, and you should become infected with it, how many germs would there be in your body at the end of ten hours? Twenty hours? One month! What prevents them from multiplying as fast as they might?

243. Project.—Secure several kinds of food and vegetables. Cut the vegetables in slices and mix the foods with water. Keep them warm and moist. The class should see them each day. Which foods are attacked the more readily? Are any resistant to decay?

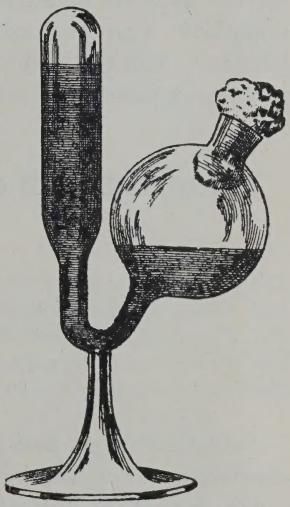


FIG. 49.—Fermentation tube for the study of gas formation by yeasts and bacteria. (*From Pitfield after Williams.*)

244. Committee Field Trip.—Some members of the class may go into the woods and find shelf fungi growing on trees. Note whether the trees are alive or dead. On what kinds of trees are they found? Bring some of the specimens to the class and put them in the museum. Give a report of your trip to the class and file a record of it with the archives committee.

245. Museum Exhibit.—The **museum committee** will prepare an exhibit of the various kinds of fungi which may be in the cases. Those which are harmful to our fruit trees are of great economic importance. Edible mushrooms which have been preserved in formalin may be seen now and a field trip planned for the spring, but more of them are to be found in the fall. If there is a mushroom cellar in the city it may be possible to visit it.

246. Yeast plants may be grown in dilute solutions of sugar, glucose, honey, sirup, or dough. Some of the material may be put

in fermentation tubes, and some of them placed in a refrigerator and some in a warm place. Which shows the most gas at the top of the tube? Smell of the cultures. What is the gas which is produced? Some of it may be passed from a flask through a tube into some fresh limewater. How does this prove the gas to be carbon dioxide?

247. Reports.—How is grain alcohol made on a commercial basis? How is cider made? How is vinegar made? Read the reports to the class.

248. Questions.—Why does salt pork keep? Why does smoked meat keep? How does sugar preserve? How does vinegar preserve? Why do tomatoes keep better when canned than corn or pumpkin? Can you make pumpkin keep when canned in the kitchen? Will teeth which are kept perfectly clean decay? Which is better, a broom or a vacuum cleaner?

32. BACTERIA AND CONTAGIOUS DISEASES OF MAN

References

Civic and Economic Biology, Atwood, Studies 58 and 59.
Civic Biology, Hodge and Dawson, Chaps. XXI–XXIII.
Civic Biology, Hunter, Chap. XI.
New Essentials of Biology, Hunter, Chap. XXX.
Practical Botany, Bergen and Caldwell, Ginn & Co.

Do not experiment with bacteria which cause disease in man. It is dangerous. They may be studied from models, charts, and pictures.

249. Statistical Projects.—Consult bulletins of the departments of health—national, state, and city—and make charts showing the decrease in deaths from typhoid, yellow fever, tuberculosis, and smallpox in recent years. To what has this been due?

250. Make charts to show the increase in certain seasons of the year of pneumonia, malaria, typhoid fever, and summer complaint. What causes this seasonal fluctuation?

251. Collect statistics to show the value of *vaccination* for smallpox, and the use of antidiptheric serum. Do these figures prove that these practises are valuable?

Collect statistics to show the decrease in **deaths of infants** in recent years? Does the milk inspection and quarantine enforcement help in this matter?

Collect figures which show that **cancer** is increasing. How do you account for this?

252. Topics may be prepared giving the symptoms, incubation periods, and methods of treatment for some of our common contagious diseases.

253. References for the above may be difficult to find. The journal of the American Medical Association is valuable, as are other reliable magazines. You should not trust all books and periodicals for your information. There is much incorrect information in the current literature on the subject of disease and health.

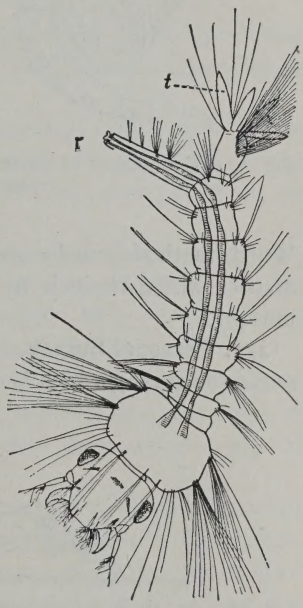


FIG. 50.—The larva of *Culex pipiens*. *t*, Tracheal gills; *r*, respiratory tube. (*Entomology*, *Folsom*.)

254. Life History of the Mosquito.—If it is now spring, the eggs and larvæ of mosquitoes may be found in stagnant water. Let each member of the class search for them. Report all of the places where they are found. Place the wrigglers in screened aquaria in the laboratory and watch them develop. Specimens may be taken out and drawn in outline. Make a series to show how they look at different ages. Adult mosquitoes may be dried and placed on microscope slides, then covered with a drop of balsam, and a cover glass may be pressed down upon it. This preparation is not perfect but it will be of value in studying the parts of the mosquito under the microscope. Find the antennæ of the males and females and compare. Note the long legs. Can mosquitoes stand on the surface of quiet water? Do you know any other creatures which can? How many wings has a mosquito? Why do they buzz? Only the females do this.

Find the probosis and distinguish its parts. See Studies 25 and 58 in Atwood's Biology.

Place some mosquito larvæ in an aquarium with goldfish and minnows. (?) Make a list of the ways of fighting mosquitoes.

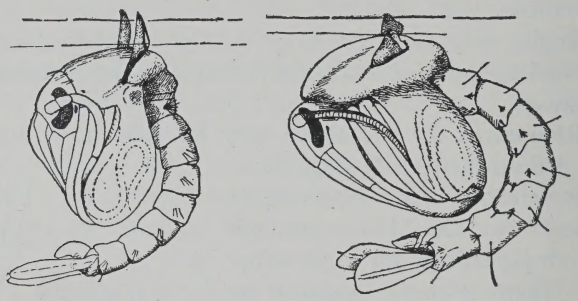


FIG. 51.—Comparison of the pupæ of *Culex* (at left) and *Anopheles* (at right)—enlarged. (*From Howard.*)

Which methods can be used in your community? If you live in a district where there is no malaria, is it worth while to fight the mosquito?

255. Personal Survey.—See *General Science*, Bowden, p. 596 and make the survey which is outlined there. If you have made it last

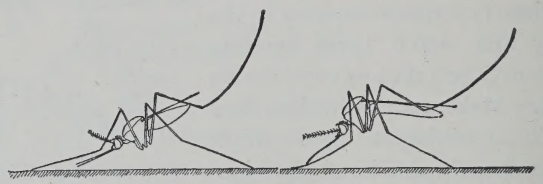


FIG. 52.—Anopheles mosquito at left, culex at right, to show their characteristic attitudes when at rest. (*Elements of Animal Biology, Holmes.*)

year, repeat it now and note any improvement which may appear. Be especially accurate in the examination of your skin, eyes, ears, nose, and mouth. You will not be required to show your report to the members of your class.

33. CONTAGIOUS DISEASES OF PLANTS

References

Fundamentals of Botany, Gager, Chaps. XIX to XXI.
Fungus Diseases of Plants, Duggar, Ginn and Co.
Mycology and Plant Pathology, Harshberger, P. Blakiston's Son & Co.
Civic and Economic Biology, Atwood, Studies 60 and 61.
Principles of Botany, Bergen and Davis, Ginn and Co.
Bulletins of the United States Department of Agriculture, and of the States.

256. Charts.—See Fig. 305 in Atwood's Biology and make similar charts to show the life histories of other fungi which cause diseases in plants.

257. Exhibits may be made of the specimens which are in the museum. Collect as much material showing plant diseases as you can. Some of it must be kept in formalin, but much of it can be dried.

258. Reports may be prepared and given on the more common **plant diseases.** Describe how they are caused. What parts of the plant are affected. How they are carried. How they pass the winter. How they are treated and cured or eliminated.

259. Table.—Make a table listing the common **plant diseases,** the plants which they injure, and the method of preventing or fighting them. Let each student work on a chart, exhibit, report, or table.

260. Lilac mildew has been a favorite for the study of a parasitic fungus for a long time. Gather the leaves of the lilac and dry them. View the spore cases under the microscope and draw them. How do the filaments of the fungus emerge from the leaf? There is a similar fungus on the leaves of willow which is good material for study. Consult a reference and learn the life history.

34. WEEDS

References

Practical Botany, Bergen and Caldwell, Ginn & Co., Chap. XXV.
Civic and Economic Biology, Atwood, Study 62.
Civic Biology, Hodge and Dawson, Chap. VII.

The departments of agriculture of Minnesota, Michigan, Ohio, and Wisconsin issue excellent bulletins on weeds. There are several issued by the U. S. Department of Agriculture.

261. Field Trip.—If it is now spring, go into the fields and find such weeds as you can. Learn their names and get as much of the following information from literature and by observation as possible.

How large does the weed get? Where does it grow? What soil is best suited to it? Can it grow in water? Is it easily frozen? Does its root live over winter? What crops does it damage the most? Has it any other methods of reproduction than by seed? How are its seeds scattered? Does it produce many seeds? Is it poisonous? Does it have a bad taste or smell? Is it extensively eaten by animals or insects? Is it easily uprooted or trampled out? Can it grow well in the shade? Does it harbor any harmful insects? Does it produce burs, berries, or large seeds? Has it a blossom? What effect might the above have on the ability of the weed to maintain itself? It may be possible to collect the above in the form of a table for the common weeds of your community.

262. Survey.—The survey committee may look for poison ivy, barberry, poison sumach, poison hemlock, poison oak, jimson weed, and fennel. Can some of these weeds and shrubs be removed? Keep a record of where they were found and the next class will follow up the work of their eradication.

263. The following figures in Atwood's Biology are pictures of weeds. Which ones of them have you found? Figs. 10, 26, 28, 29, 40, 41, 43, 47, 63, 64, 106, 107, 108, 156, 163, 174, 176, 178, 180, 181, 182, 191, 192, 194, 195, 199, 202, 311, 312, 313, 314, 316, 317.

264. Weed Seed.—Examine a sample of clover seed which contains the seeds of weeds. Use a lens. Compare the weed seeds which you find with those shown in Fig. 317, Atwood's Biology. How many kinds have you found? What per cent of the seed was

weed seed? What is the law in your state in regard to weed seed in seed which is sold for planting?

35. PARASITIC WORMS

References

General Zoology, Pearse, Henry Holt & Co.
Textbook of Zoology, Galloway, P. Blakiston's Son & Co.
Civic and Economic Biology, Atwood, Study 63.
Civic Biology, Hodge and Dawson, Chap. XXIV.

265. The tapeworm may be observed in the laboratory by passing a preserved specimen around the class. Microscope slides on which are mounted proglottides to show their parts may be had from the dealers. These may be observed under the microscope and compared with Fig. 319 in Atwood's Biology and drawn. Label all features completely. Ward, Rochester, N. Y. makes an excellent model of a proglottid of the tapeworm. It may be drawn by the students. How do the eggs get out of the ovaries to the exterior? What is the function of the uterus?

266. Ascaris may be observed from bottles containing preserved specimens. Sometimes eggs may be found in the females. They may be seen under the microscope.

267. Trichina may be studied from microscope slides. They may be had from the dealers. If the slides are made from the flesh of the rat or pig which contains the larvæ, the student should consult Fig. 321 in Atwood's Biology and make sketches of what he sees under the microscope.

268. The **hook-worm** may be studied from slides, but few schools are supplied with such material, and it is not easily obtained.

269. Topics.—Secure bulletins from the U. S. Public Health Service and report on such phases of the **hook-worm problem** as may seem advisable.

270. Diagrams of the life histories of various parasitic worms may be made by students. These may be put in the notebooks or on the board. Each diagram should be accompanied by a description. The texts by Pearse, Galloway, and Hodge and Dawson are good references.

36. INSECT PESTS

References

Civic and Economic Biology, Atwood, Studies 64–67.
Civic Biology, Hodge and Dawson, Chaps. X–XV.
Economic Zoology, Kellogg and Doan.
Elementary Biology, Gruenberg, Chaps. LXXV and LXXIV.
Biology for Beginners, Moon, Chaps. XXIII–XXV.
Economic Entomology, Lochhead, P. Blakiston's Son & Co.
Entomology, Folsom, P. Blakiston's Son & Co.
Elementary Entomology, Sanderson and Jackson, Ginn & Co.
Injurious Insects, O'Kane, Macmillan & Co.

271. Excursion.—If there is a greenhouse near the school, it may be profitable to make a trip to it to study their methods of controlling insect pests.

272. Exhibits.—The **museum committee** should place on exhibit such injurious insects as are in its possession. Write out a legend for each exhibit stating something of the life history, damage done, and methods of control.

273. Survey.—Let each student be on the watch for insects as they appear this spring. Capture them and bring them to the class. Recognize them as beetles, flies, butterflies, etc. and try to learn their individual names and what they live on. Keep a record of the earliest appearance of insects common to your community and file the record with the archives committee.

274. Topics and Reports.—Let each student prepare a paper on some harmful insect. Make a chart to go with the paper if you can. For an idea as to how to make such a chart, see Figs. 315, 324, 326, and 335 in Atwood's Biology and similar figures in the other references.

275. Tables.—Prepare a table of the sprays which are used as **stomach poisons** and state in the table what kinds of insects are fought with each spray.

Make a similar table for sprays which are **contact poisons.**

Make another table of **stomach poisons** which are not applied through a spraying nozzle.

276. Laboratory work should be done on an insect which has **chewing or biting mouth parts** and on one which has **sucking mouth**

parts. See Figs. 32, 328, 329, and 330 in Atwood's Biology and the figures of the grasshopper in Unit 6 of this manual. Insects having chewing mouth parts which are easily studied are caterpillars, grubworms, beetles, dragon flies, and grasshoppers. Insects having piercing and sucking mouth parts which may be studied are squash bugs, assassin bugs, electric light bugs, cicadas, and some of the flies. After carefully consulting the figures in reference books, each student

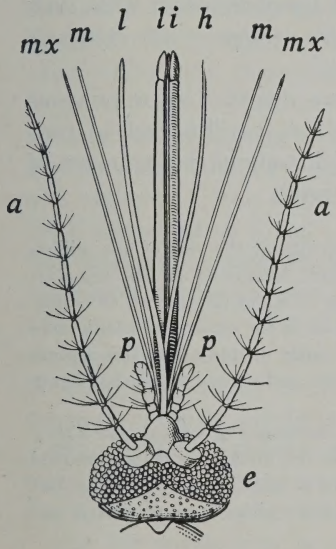


FIG. 53.

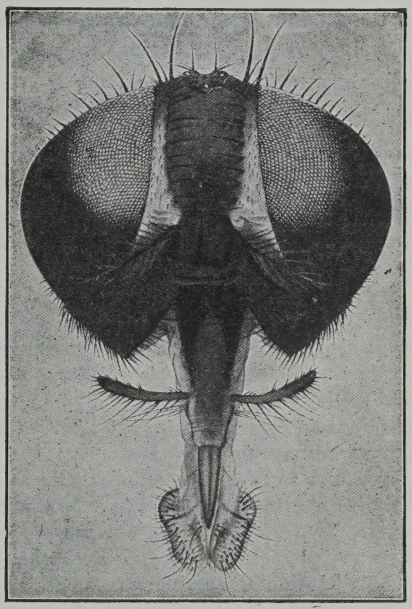


FIG. 54.

FIG. 53.—Mouth parts of the mosquito to show a type of piercing mouth parts. *a*, Antenna; *e*, compound eye; *h*, hypopharynx; *l*, labrum-epipharynx; *li*, labium; *m*, mandible; *mx*, maxilla; *p*, maxillary palpus. (*From Folsom, after Dimmock.*)

FIG. 54.—The head of the housefly. (*From Herms.*)

should make a study, with the aid of a lens, of the mouth parts of a chewing and a sucking insect. Make sketches of the mouth parts and label them carefully. Do you understand why stomach poisons do not kill bugs? If bugs do not eat the leaves of a plant, how do they do it damage? Which is the more primitive type of mouth?

In examining mouth parts of insects, the student should use a fine tweezers and a needle point. Those of the chewing insects may be removed and sketched apart from the head or they may be left on. It will be best to leave the mouth parts of sucking insects on the head and sketch them in that way. They should be separated for observation with great care or they will be broken. The needle point is best for this purpose. Thrust it between them near the head and gently work it down to the point of the beak parting the mouth parts as you do so.

277. **Exhibit.**—The **supplies committee** should make an exhibit of the various **chemicals which are used in fighting insects.** They may be put in glass bottles and set out for observation with such notes as may seem appropriate. *Caution.—Some of the chemicals are very poisonous.*

278. **Review.**—If the **grasshopper** was dissected in a previous study, it should be reviewed now; but if not, it will be well to turn to the directions there and make a careful study of the structure of the grasshopper considered as a typical insect.

279. **News Item.**—Flies are being bred in our city at the rate of one million every twenty-four hours. The committee on civic surveys of the biology class of the high school reports finding a manure heap on River Avenue which is producing a million flies every day. We wonder if all of the citizens of Blank have been getting their share of these flies. A statistician on the committee reports that there are 104 flies for each family in the city, and several times that figure for each grocery store per day.

We hasten to inform the curious that it will be necessary to start at once if they desire to see this marvel of insect breeding, for the manure is being removed today. We regret to announce the destruction of so beautiful a fly paradise, but the school physician held a conference with its owner with the result that it was sold for fertilizer at a satisfactory profit.

The above news item is a gem of biological literature. It condemns no one, is somewhat humorous, and lets those who have manure piles know indirectly that they must be removed. There should be considerable manure for sale the day following the publication of such an article. Is it necessary to publish such an article in the press of your city? When the fly season opens, there should be no manure piles. Such piles do little harm in the winter, but when spring comes the flies which have wintered over in them in the form of maggots and pupæ begin to come out, and other flies lay their eggs there. Appoint a committee to make a survey.

280. Fly Breeding Project.—Secure some **fly eggs or young larvæ** and some manure. Place them in a glass jar and observe their development from day to day. Place them in the care of some student who will see that the culture is kept properly until the flies develop. Keep a record of the length of the stages of development. Does food or temperature affect the length of the stages?

281. Laboratory Study.—With the aid of a lens and the compound microscope the **fly** should be carefully examined. Dip each fly in a solution of formalin before handling it to kill any germs which may be on it. The **wings** are gauzy and covered with hairs. Note the veins which keep them stiff. The **head** is possessed of two large compound eyes. Find the bristle-like antennæ. The mouth parts are adapted for lapping up fluids. Can you identify the mandibles, maxillæ, and labium? The **body** is divided into a head, thorax, and abdomen. The **thorax** is composed of three fused somites. Each somite bears a leg. Note the hairs on the legs. Are they well adapted to carrying bacteria? Place a **fly's foot** under the compound microscope and view it. Find the two hooks, the pad, and note the hairs. The **abdomen** is composed of somites which are easily distinguished. How many are there? Note the hairs. Is the fly a good carrier of germs? If time permits, sketches of various parts of the fly may be made.

283. Fly Trap Exhibit.—A committee may be appointed to secure some fly traps, or they may be made. Exhibit them to the class. See Hodge and Dawson's Biology, Chap. X.

284. Fly poison may be made by placing a little sugar or honey in a saucer of water and adding a small amount of formalin. It may be well to place a slip of paper in the dish for the flies to light on. All water must be removed from the room. Flies require large quantities of water and are fond of water containing a little formalin. If there are flies in the laboratory, this experiment may be tried; but there must be no water for them to get at, other than the poison.

285. Arachnids.—Examine specimens of spiders, centipeds, and millipeds and make out the tables on pp. 424 and 432 of Atwood's Biology.

286. Reports may be given on the life histories and methods of control of various arachnid pests. Government bulletins will be found to be the best references.

287. Spider webs may be studied as projects. How are they made? What are they used for? How many kinds are there? A few minutes of the recitation hour may be devoted to an exchange of information and ideas on spider webs.

37. RATS AND MICE

References

Civic and Economic Biology, Atwood, Study 68.
Civic Biology, Hodge and Dawson, Chap. XVII.
Bulletins of the U. S. Department of Agriculture.

288. David Lantz estimates that a rat does two dollars worth of damage every year of its life. How much wheat would it eat to amount to this figure? Corn? Flour?

Each student will make a list of the ways in which rats have been known personally to destroy property. Bring the lists to class. Compare and average them. It may be well to collect the averages in a table.

289. Bubonic Plague.—Consult references and make a diagram of the life history of bubonic plague.

290. Survey.—A survey committee should collect some information on the **rat problem** in your city. Where are they the most abundant? Are there any open sewers? Can a movement be started and carried out to have the sewers covered? Are there any garbage dumps in the city? Is it possible to have the garbage burned? Are any of the merchants or manufacturers suffering loss by rats? In making surveys, you should always be courteous and diplomatic.

291. Problem.—If a rat brings forth ten young to a litter, and breeds four times in a year, how many rats will there be at the end of five years?

38. FISH AND POND LIFE

References

Fish Culture in Ponds and other Waters, Meehan, Macmillan & Co.
Civic and Economic Biology, Atwood, Study 69.
Civic Biology, Hodge and Dawson, Chap. XXVII.
Biology for Beginners, Moon, Chap. XXVII.
General Zoology, Pearse, Henry Holt & Co.
Life of Inland Waters, Needham and Lloyd, Comstock Pub. Co.

292. Excursion.—If there is a pond, lake, or stream in the vicinity, an excursion should be made to it. Dip nets, glass jars, pails, etc. should be taken along. What animals do you find in the water? Is the water clear, running, muddy, or stagnant? What is the condition of the bottom? What is the source of supply of the body of water which you are visiting?

What kinds of insects are present? What kinds of molluscs? What kinds of plants? What kinds of crustaceans? List them.

Catch as many of the animals which live in the pond as you can. Place them in aquaria in the laboratory and study them. What ones are eaten by fish? Which ones eat others? What is the source of all food in water?

Make a list of the fishes which are known to inhabit the body of water. Do you know what each feeds on? What might be done to increase the number of fish which could be taken from the pond each year?

Discuss the questions raised above when you meet in class the next day.

293. Aquaria.—Review the work done with aquaria last fall. Are any of the aquaria in the same condition in which they were left last fall? What changes have taken place? Review the chemical cycles in ponds and aquaria. Understand the relationships of plants and animals in water. What kinds of fish have you been able to keep in the laboratory?

39. THE PERCH (DISSECTION)

References

Comparative Vertebrate Dissection, Atwood, P. Blakiston's Son & Co.
Laboratory Directions in Elementary Zoology, Guyer, U. of Wis. Press.
General Zoology, Linville and Kelley, Ginn & Co.
Civic and Economic Biology, Atwood, Study 69.

294. Study a Live Fish in Water.—How does it pass water over the gills? How does it swim? Are all of the fins used? Note the fins. The one at the tail is the **caudal.** Those along the back are the **dorsal fins.** Those under the tail are the **anal fins.** Those which are paired are the **pectoral fins** near the head, and the **pelvic fins** along the sides of the body farther back.

Find the **nostrils.** What are they used for? Find the **eyes.** Are they movable? Feed the fish. How do they find the food?

Study the **scales.** How are they arranged? Are they all of the same size? Note how they lap over the ones behind them. Find the **lateral line** which is a line from above the eye along the side of the body to the tail. It is a line of sense organs.

Draw the fish which you have observed. Label all of its parts carefully.

295. Dissection of Perch.—Specimens with the ventral wall of the body cut away may be kept in formalin from year to year and used in this study for examination, or fresh specimens may be dissected. Make a cut along the mid-line of the body and carry it forward to the pectoral girdle and back to the anus. Now cut away the sides of the abdominal walls. This exposes the visceral organs of the perch. Push a probe into the mouth and find where it enters the **stomach.** Note the shape of this organ. Find the **pyloric appendages** at the place where the stomach and intestine meet. How many are there? What is their function? The **liver** is the dark red organ forward from the stomach. How many lobes has it? Can you find the green **gall bladder?** Trace the coiled **intestine** through the **fat** which surrounds it to its opening to the outside. How many coils are there? Can you find the **pancreas** and **spleen?** What are the functions of these organs? The pancreas is in a very simple form in the perch.

The **reproductive organs** are situated along the intestine and vary greatly in size with the season of the year. Trace their openings to the exterior. The **air bladder** is the silvery sac in the dorsal part of the body-cavity. What is its shape? How is it attached? The **kidneys** are situated between the bladder and the backbone. They are of a dark red-brown color. What is their extent?

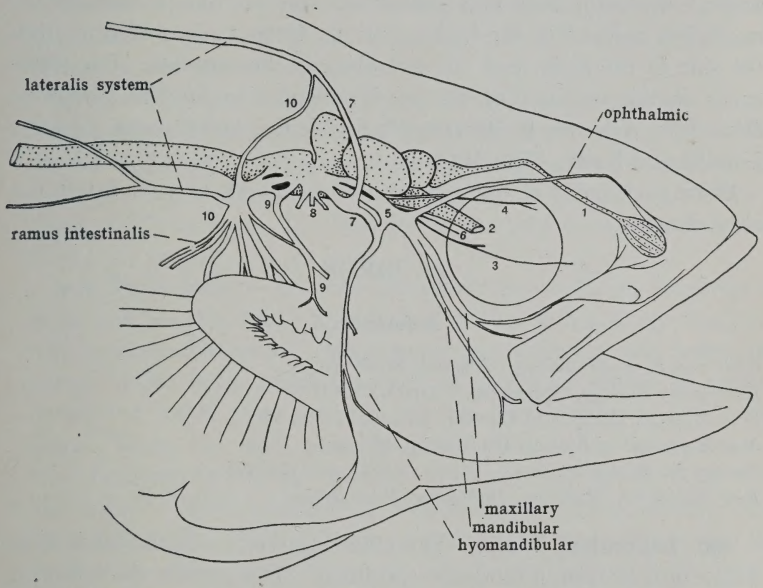


FIG. 55.—The brain and ten cranial nerves of the perch as seen from side view. (*Comparative Vertebrate Dissection, Atwood.*)

The **heart** is situated between the gills in the thick triangular area. Cut into it and observe the heart. Find the **atrium** (auricle) and the **ventricle.** It will be difficult for a student of high school grade to make out the blood vessels without injection, but they are charted in Figs. 98 and 99 in Atwood's Biology. Understand how the blood traverses the body of a fish and compare it with that of man and the frog.

The **brain** and **cranial nerves** of the perch are shown in the illustration. Cut away the roof of the skull and remove the fatty material

which surrounds the brain. The most anterior lobes comprise the **cerebrum,** the second pair are the **optic lobes,** and the third unpaired lobe is the **cerebellum.** Try to find the cranial nerves which are shown in the illustration. You may not be able to find them all.

The **muscles** of the perch are of the segmented type along the sides of the body. They are an evidence of the fact that vertebrated animals are segmented as is the earthworm, but these evidences are much less evident in the higher forms. Strip a piece of skin from the side of the body and tail and observe the muscles. For references on the anatomy of the perch consult *Comparative Vertebrate Dissection,* Atwood, P. Blakiston's Son & Co. and *General Zoology,* Linville and Kelly, Ginn & Co.

Draw such parts of the anatomy of the perch as your instructor may direct.

40. BIRDS

References

Civic and Economic Biology, Atwood, Study 70.
Elementary Biology, Gruenberg, Chap. LXXVII.
Civic Biology, Hodge and Dawson, Chaps. IV and V.
New Essentials of Biology, Hunter, pp. 286–302.
Biology for Beginners, Moon, Chaps. XXXI and XXXII.
Bird Neighbors, Blanchan, Doubleday Page & Co.

296. Laboratory Work.—The following study may be made from a live bird or from a mounted specimen. Distinguish the following regions: **head, neck, body,** and **tail.** The **bill** is peculiar to birds. Does it contain any teeth? Find the **nostrils.** Note their shape and position. Are they covered with feathers? Find the **eyes.** Are they possessed of lids? What is the color of the eyes? What is the shape of the pupil? Find the **ears.** Is there an external ear? How is the ear covered?

The neck and body are covered with **feathers** which are so arranged as to shed the rain and to offer as little resistance to flight as possible. How are the **wings** folded? How many joints are there? The long feathers are firmly set in the flesh of the wing. Note how they overlap when the wing is spread. Examine a large feather. The part which was in the flesh is the **quill.** The stiff central portion

is the **rachis.** The **barbs** run out from the rachis and possess **barbules** which lock them together.

How many joints are there in the **legs?** How much of the leg is covered with feathers? Note how the **scales** are arranged. How many **toes** are there? On what part of the foot does the bird walk? Are the feet webbed? What are the toe nails fitted for?

The **tail** of a bird is short, but it may contain long feathers. Compare them with those of the wings. Is the tail broad or pointed. What are the uses of birds' tails?

Draw a bird from side view in outline and label its parts.

297. Migration Chart.—Make a tabulation of the dates of arrival of the migratory birds which pass through your section of the country. Let each student be on the watch for birds and record those which he sees. Post the list in the school and compare lists from year to year.

298. Field Study.—Go into the woods and fields on Saturday in groups of less than ten. If there are too many in a group, the birds will be frightened away. Have notebooks with you and record the names of the birds which you see. These trips should be started before the leaves come out, because the birds are more easily seen then. When the birds begin to build their nests, the process of nest building should be observed. In what situation does each bird build? What materials go into the nest? How are they fastened together? Do both birds assist in building? When are the eggs laid? What is their color? Do both birds incubate them? What are the young like? Do both birds feed them? What do they feed them? A blind may be made and a watcher placed in it to make a daily record of the food given to the nestlings. The watcher should be relieved every hour. Are the birds which you have watched beneficial? Do owls hunt all night? It will not be necessary to watch the song birds after dark.

Aside from nest building the **songs** and **colors** of birds are the most interesting. Learn to know them by their colors and songs. Note differences in males and females. What differences may be noted in young and old birds? It is difficult to see the color of a bird when it is between you and the sun, or when it is in the bright light. Colors show best in quiet woods.

Watch a sparrow's nest while the young are being feed. You may be surprised at the large number of insects which are fed to the young. Sparrows do much good and some harm.

299. Bird Calendar.—List all of the birds of the community as summer residents, winter residents, permanent residents, and migrants. Give the dates of arrival and departure. This calendar should be started by the first class and corrected and amplified from year to year. It should be placed in charge of the archives committee.

300. Survey.—A tabulation may be made of the shrubs in the community which bear fruits which are eaten by birds. What can be done to increase the number of such shrubs? Will this have a tendency to increase the number of birds in the community?

301. Bird Boxes.—Arrange with the manual training department to make some bird boxes. Have an exhibit of them. When they are set up, they should be put out of the way of cats.

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